
ACM TEMPLATE

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1 To Do List

所有带*的内容。。。

可以从原来的模板里面继承一些好东西过来。

set,map,multiset等的搞基用法，以及注意事项。

生成树计数

2 注意事项

10^6 数量级慎用后缀数组

TLE的时候要冷静哟。。

思考的时候结合具体步骤来的话 会体会到一些不同的东西

C++与G++是很不一样的。。。

map套字符串是很慢的。。。

栈会被记录内存。。。

浮点数最短路要注意取 \leq 来判断更新。。。

注意 long long

不要相信.size()

重复利用数组时 小心数组范围

先构思代码框架 每当实际拍马框架变化时 停手 重新思考

有时候四边形不等式也是帮得上忙的 dp 优化是可以水的

结构体里面带数组会非常慢,有时候 BFS 把数组压成数字会快很多。

```
1 void fun(int a[])
2 {
3     printf("%d\n", sizeof(a));
4 }
```

结果是 sizeof(a[0]),如果传数组指针然后要清空的话不要用 sizeof。

sqrt 某些时候会出现 sqrt(-0.00)的问题。

将code::blocks的默认终端改成gnome-terminal

```
1 gnome-terminal -t $TITLE -x
```

最小割集找法 在残量网络中从源点出发能到的点集记为S原图中S到S'的边即是最小割集

double全局变量初始值可能不是0

3 字符串处理

3.1 *AC自动机

3.1.1 指针

```

1  const int CHAR=26;
2  const int TOTLEN=500000;
3  const int MAXLEN=1000000;
4  struct Vertex
5  {
6      Vertex *fail,*next[CHAR];
7      Vertex(){}
8      Vertex(bool flag)//为什么要这样写?
9      {
10         fail=0;
11         memset(next,0,sizeof(next));
12     }
13 };
14 int size;
15 Vertex vertex[TOTLEN+1];
16 void init()
17 {
18     vertex[0]=Vertex(0);
19     size=1;
20 }
21 void add(Vertex *pos,int cha)
22 {
23     vertex[size]=Vertex(0);
24     pos->next[cha]=&vertex[size++];
25 }
26 void add(vector<int> s)
27 {
28     int l=s.size();
29     Vertex *pos=&vertex[0];
30     for (int i=0; i<l; i++)
31     {
32         if (pos->next[s[i]]==NULL)
33             add(pos,s[i]);
34         pos=pos->next[s[i]];
35     }
36 }
37 void bfs()
38 {
39     queue<Vertex *> que;
40     Vertex *u=&vertex[0];
41     for (int i=0; i<CHAR; i++)
42         if (u->next[i]!=NULL)
43         {
44             que.push(u->next[i]);
45             u->next[i]->fail=u;

```

```

46     }
47     else
48         u->next[i]=u;
49     u->fail=NULL;
50     while (!que.empty())
51     {
52         u=que.front();
53         que.pop();
54         for (int i=0; i<CHAR; i++)
55             if (u->next[i]!=NULL)
56             {
57                 que.push(u->next[i]);
58                 u->next[i]->fail=u->fail->next[i];
59             }
60             else
61                 u->next[i]=u->fail->next[i];
62     }
63 }

```

3.1.2 非指针

```

1 struct Trie
2 {
3     int next[50][10],fail[50];
4     bool end[50];
5     int L,root;
6
7     int newNode()
8     {
9         for (int i = 0;i < 10;i++)
10             next[L][i] = -1;
11         end[L] = false;
12         return L++;
13     }
14
15     void Init()
16     {
17         L = 0;
18         root = newNode();
19     }
20
21     void Insert(char s[])
22     {
23         int now = root;
24         for (int i = 0;s[i] != 0;i++)
25         {
26             if (next[now][s[i]-'0'] == -1)
27                 next[now][s[i]-'0'] = newNode();
28             now = next[now][s[i]-'0'];
29         }
30         end[now] = true;
31     }

```

```

32
33     void Build()
34     {
35         queue<int> Q;
36         for (int i = 0; i < 10; i++)
37             if (next[root][i] == -1)
38                 next[root][i] = root;
39             else
40             {
41                 fail[next[root][i]] = root;
42                 Q.push(next[root][i]);
43             }
44         while (!Q.empty())
45         {
46             int now = Q.front();
47             Q.pop();
48             end[now] |= end[fail[now]];
49             for (int i = 0; i < 10; i++)
50                 if (next[now][i] == -1)
51                     next[now][i] = next[fail[now]][i];
52                 else
53                 {
54                     fail[next[now][i]] = next[fail[now]][i];
55                     Q.push(next[now][i]);
56                 }
57         }
58     }
59 };

```

3.2 后缀数组

3.2.1 DC3

所有下标都是0 n-1, height[0]无意义。

```

1 //所有相关数组都要开三倍
2 const int maxn = 300010;
3 # define F(x) ((x)/3+((x)%3==1?0:tb))
4 # define G(x) ((x)<tb?(x)*3+1:((x)-tb)*3+2)
5 int wa[maxn * 3], wb[maxn * 3], wv[maxn * 3], ws[maxn * 3];
6 int c0(int *r, int a, int b)
7 {
8     return r[a] == r[b] && r[a + 1] == r[b + 1] && r[a + 2] == r[b
9         + 2];
10 }
11 int c12(int k, int *r, int a, int b)
12 {
13     if (k == 2) return r[a] < r[b] || r[a] == r[b] && c12(1, r, a +
14         1, b + 1);
15     else return r[a] < r[b] || r[a] == r[b] && wv[a + 1] < wv[b +
16         1];
17 }
18 void sort(int *r, int *a, int *b, int n, int m)

```

```

16 {
17     int i;
18     for (i = 0; i < n; i++) wv[i] = r[a[i]];
19     for (i = 0; i < m; i++) ws[i] = 0;
20     for (i = 0; i < n; i++) ws[wv[i]]++;
21     for (i = 1; i < m; i++) ws[i] += ws[i - 1];
22     for (i = n - 1; i >= 0; i--) b[--ws[wv[i]]] = a[i];
23     return;
24 }
25 void dc3(int *r, int *sa, int n, int m)
26 {
27     int i, j, *rn = r + n, *san = sa + n, ta = 0, tb = (n + 1) / 3,
        tbc = 0, p;
28     r[n] = r[n + 1] = 0;
29     for (i = 0; i < n; i++) if (i % 3 != 0) wa[tbc++] = i;
30     sort(r + 2, wa, wb, tbc, m);
31     sort(r + 1, wb, wa, tbc, m);
32     sort(r, wa, wb, tbc, m);
33     for (p = 1, rn[F(wb[0])] = 0, i = 1; i < tbc; i++)
34         rn[F(wb[i])] = c0(r, wb[i - 1], wb[i]) ? p - 1 : p++;
35     if (p < tbc) dc3(rn, san, tbc, p);
36     else for (i = 0; i < tbc; i++) san[rn[i]] = i;
37     for (i = 0; i < tbc; i++) if (san[i] < tb) wb[ta++] = san[i] *
        3;
38     if (n % 3 == 1) wb[ta++] = n - 1;
39     sort(r, wb, wa, ta, m);
40     for (i = 0; i < tbc; i++) wv[wb[i] = G(san[i])] = i;
41     for (i = 0, j = 0, p = 0; i < ta && j < tbc; p++)
42         sa[p] = c12(wb[j] % 3, r, wa[i], wb[j]) ? wa[i++] : wb[j
            ++];
43     for (; i < ta; p++) sa[p] = wa[i++];
44     for (; j < tbc; p++) sa[p] = wb[j++];
45 }
46 //str和sa也要三倍
47 void da(int str[], int sa[], int rank[], int height[], int n, int m
    )
48 {
49     for (int i = n; i < n * 3; i++)
50         str[i] = 0;
51     dc3 (str , sa , n + 1 , m);
52     int i, j, k;
53     for (i = 0; i < n; i++)
54     {
55         sa[i] = sa[i + 1];
56         rank[sa[i]] = i;
57     }
58     for (i = 0, j = 0, k = 0; i < n; height[rank[i ++]] = k)
59         if (rank[i] > 0)
60             for (k ? k-- : 0 , j = sa[rank[i] - 1]; i + k < n && j
                + k < n &&
61                 str[i + k] == str[j + k]; k ++);

```

62 | }

3.2.2 DA

这份似乎就没啥要注意的了。

```

1  const int maxn = 200010;
2  int wx[maxn],wy[maxn],*x,*y,wss[maxn],wv[maxn];
3
4  bool cmp(int *r,int n,int a,int b,int l)
5  {
6      return a+l<n && b+l<n && r[a]==r[b]&&r[a+l]==r[b+l];
7  }
8  void da(int str[],int sa[],int rank[],int height[],int n,int m)
9  {
10     int *s = str;
11     int *x=wx,*y=wy,*t,p;
12     int i,j;
13     for(i=0; i<m; i++)wss[i]=0;
14     for(i=0; i<n; i++)wss[x[i]=s[i]]++;
15     for(i=1; i<m; i++)wss[i]+=wss[i-1];
16     for(i=n-1; i>=0; i--)sa[--wss[x[i]]]=i;
17     for(j=1,p=1; p<n && j<n; j*=2,m=p)
18     {
19         for(i=n-j,p=0; i<n; i++)y[p++]=i;
20         for(i=0; i<n; i++)if(sa[i]-j>=0)y[p++]=sa[i]-j;
21         for(i=0; i<n; i++)wv[i]=x[y[i]];
22         for(i=0; i<m; i++)wss[i]=0;
23         for(i=0; i<n; i++)wss[wv[i]]++;
24         for(i=1; i<m; i++)wss[i]+=wss[i-1];
25         for(i=n-1; i>=0; i--)sa[--wss[wv[i]]]=y[i];
26         for(t=x,x=y,y=t,p=1,i=1,x[sa[0]]=0; i<n; i++)
27             x[sa[i]]=cmp(y,n,sa[i-1],sa[i],j)?p-1:p++;
28     }
29     for(int i=0; i<n; i++) rank[sa[i]]=i;
30     for(int i=0,j=0,k=0; i<n; height[rank[i++]]=k)
31         if(rank[i]>0)
32             for(k?k--:0,j=sa[rank[i]-1]; i+k < n && j+k < n && str[
33                 i+k]==str[j+k]; k++);

```

3.3 后缀三兄弟

```

1  #include <cstdio>
2  #include <cstring>
3  #include <algorithm>
4  using namespace std;
5  const int CHAR = 26;
6  const int MAXN = 100000;
7  struct SAM_Node
8  {

```

```

9     SAM_Node *fa,*next[CHAR];
10    int len;
11    int id,pos;
12    SAM_Node() {}
13    SAM_Node(int _len)
14    {
15        fa = 0;
16        len = _len;
17        memset(next,0,sizeof(next));
18    }
19 };
20 SAM_Node SAM_node[MAXN * 2], *SAM_root, *SAM_last;
21 int SAM_size;
22 SAM_Node *newSAM_Node(int len)
23 {
24     SAM_node[SAM_size] = SAM_Node(len);
25     SAM_node[SAM_size].id=SAM_size;
26     return &SAM_node[SAM_size++];
27 }
28 SAM_Node *newSAM_Node(SAM_Node *p)
29 {
30     SAM_node[SAM_size] = *p;
31     SAM_node[SAM_size].id=SAM_size;
32     return &SAM_node[SAM_size++];
33 }
34 void SAM_init()
35 {
36     SAM_size = 0;
37     SAM_root = SAM_last = newSAM_Node(0);
38     SAM_node[0].pos=0;
39 }
40 void SAM_add(int x,int len)
41 {
42     SAM_Node *p = SAM_last, *np = newSAM_Node(p->len + 1);
43     np->pos=len;
44     SAM_last = np;
45     for (; p && !p->next[x]; p = p->fa)
46         p->next[x] = np;
47     if (!p)
48     {
49         np->fa = SAM_root;
50         return ;
51     }
52     SAM_Node *q = p->next[x];
53     if (q->len == p->len + 1)
54     {
55         np->fa = q;
56         return ;
57     }
58     SAM_Node *nq = newSAM_Node(q);
59     nq->len = p->len + 1;

```

```

60     q->fa = nq;
61     np->fa = nq;
62     for (; p && p->next[x] == q; p = p->fa)
63         p->next[x] = nq;
64 }
65 void SAM_build(char *s)
66 {
67     SAM_init();
68     int l = strlen(s);
69     for (int i = 0; i < l; i++)
70         SAM_add(s[i] - 'a', i+1);
71 }
72
73 SAM_Node * SAM_add(SAM_Node *p, int x, int len)
74 {
75     SAM_Node *np = newSAM_Node(p->len + 1);
76     np->pos = len;
77     SAM_last = np;
78     for (; p && !p->next[x]; p = p->fa)
79         p->next[x] = np;
80     if (!p)
81     {
82         np->fa = SAM_root;
83         return np;
84     }
85     SAM_Node *q = p->next[x];
86     if (q->len == p->len + 1)
87     {
88         np->fa = q;
89         return np;
90     }
91     SAM_Node *nq = newSAM_Node(q);
92     nq->len = p->len + 1;
93     q->fa = nq;
94     np->fa = nq;
95     for (; p && p->next[x] == q; p = p->fa)
96         p->next[x] = nq;
97     return np;
98 }
99 void SAM_build(char *s)//多串建立 注意SAM_init()的调用
100 {
101     int l = strlen(s);
102     SAM_Node *p = SAM_root;
103     for (int i = 0; i < l; i++)
104     {
105         if (!p->next[s[i] - 'a'] || !(p->next[s[i] - 'a']->len == i
106             + 1))
107             p=SAM_add(p,s[i] - 'a', i + 1);
108         else
109             p = p->next[s[i] - 'a'];
110     }

```

```

110 }
111
112 struct ST_Node
113 {
114     ST_Node *next[CHAR],*fa;
115     int len,pos;
116 }ST_node[MAXN*2],*ST_root;
117 int Sufpos[MAXN];
118 void ST_add(int u,int v,int chr,int len)
119 {
120     ST_node[u].next[chr]=&ST_node[v];
121     ST_node[v].len=len;
122 }
123 void init(int n)
124 {
125     for (int i=0;i<n;i++)
126     {
127         ST_node[i].pos=-1;
128         ST_node[i].fa=0;
129         memset(ST_node[i].next,0,sizeof(ST_node[i].next));
130     }
131     ST_node[0].pos=0;
132     ST_root=&ST_node[0];
133 }
134 void ST_build(char *s)
135 {
136     int n=strlen(s);
137     reverse(s,s+n);
138     SAM_build(s);
139     init(SAM_size);
140     for (int i=1;i<SAM_size;i++)
141     {
142         ST_add(SAM_node[i].fa->id,SAM_node[i].id,s[SAM_node[i].pos-
            SAM_node[i].fa->len-1]-'a',SAM_node[i].len-SAM_node[i].
            fa->len);
143         if (SAM_node[i].pos==SAM_node[i].len)
144         {
145             Sufpos[n-SAM_node[i].pos+1]=i;
146             ST_node[i].pos=n-SAM_node[i].pos+1;
147         }
148     }
149 }
150
151 int rank[MAXN],sa[MAXN+1];
152 int height[MAXN];
153 int L;
154 void ST_dfs(ST_Node *p)
155 {
156     if (p->pos!=-1)
157         sa[L++]=p->pos;
158     for (int i=0;i<CHAR;i++)

```



```

159         if (p->next[i])
160             ST_dfs(p->next[i]);
161     }
162     char s[MAXN+1];
163     int main()
164     {
165         gets(s);
166         ST_build(s);
167         L=0;
168         ST_dfs(ST_root);
169         int n=strlen(s);
170         for (int i=0; i<n; i++)
171             sa[i]=sa[i+1]-1;
172         for (int i=0; i<n; i++)
173             rank[sa[i]]=i;
174         reverse(s,s+n);
175         for (int i=0,j=0,k=0; i<n; height[rank[i++]]=k)
176             if (rank[i])
177                 for (k?k--:0,j=sa[rank[i]-1]; s[i+k]==s[j+k]; k++);
178     }

```

3.3.1 例题

```

1  #include <iostream>
2  #include <algorithm>
3  #include <cstdio>
4  #include <cstring>
5  using namespace std;
6
7  const int CHAR = 26;
8  const int MAXN = 100000;
9
10 struct SAM_Node
11 {
12     SAM_Node *fa,*next[CHAR];
13     int len;
14     int id;
15     int mat[9];
16     SAM_Node() {}
17     SAM_Node(int _len)
18     {
19         fa = 0;
20         len = _len;
21         memset(mat,0,sizeof(mat));
22         memset(next,0,sizeof(next));
23     }
24 };
25 SAM_Node SAM_node[MAXN*2],*SAM_root,*SAM_last;
26 int SAM_size;
27 SAM_Node *newSAM_Node(int len)
28 {
29     SAM_node[SAM_size] = SAM_Node(len);

```

```

30     SAM_node[SAM_size].id = SAM_size;
31     return &SAM_node[SAM_size++];
32 }
33 SAM_Node *newSAM_Node(SAM_Node *p)
34 {
35     SAM_node[SAM_size] = *p;
36     SAM_node[SAM_size].id = SAM_size;
37     return &SAM_node[SAM_size++];
38 }
39 void SAM_init()
40 {
41     SAM_size = 0;
42     SAM_root = SAM_last = newSAM_Node(0);
43 }
44 void SAM_add(int x,int len)
45 {
46     SAM_Node *p = SAM_last,*np = newSAM_Node(p->len+1);
47     SAM_last = np;
48     for (; p&&!p->next[x]; p=p->fa)
49         p->next[x] = np;
50     if (!p)
51     {
52         np->fa = SAM_root;
53         return;
54     }
55     SAM_Node *q = p->next[x];
56     if (q->len == p->len+1)
57     {
58         np->fa = q;
59         return;
60     }
61     SAM_Node *nq = newSAM_Node(q);
62     nq->len = p->len+1;
63     q->fa = nq;
64     np->fa = nq;
65     for (; p&&p->next[x] == q; p = p->fa)
66         p->next[x] = nq;
67 }
68 int getid(char ch)
69 {
70     return ch-'a';
71 }
72 void SAM_build(char *s)
73 {
74     SAM_init();
75     int l = strlen(s);
76     for (int i = 0; i < l; i++)
77         SAM_add(getid(s[i]),i+1);
78 }
79 char s[10][MAXN+1];
80 int ans;

```

```

81 int head[MAXN*2];
82 struct Edge
83 {
84     int to,next;
85 } edge[MAXN*2];
86 int M;
87 int n;
88 void add_edge(int u,int v)
89 {
90     edge[M].to=v;
91     edge[M].next=head[u];
92     head[u]=M++;
93 }
94 void dfs(int u)
95 {
96     for (int i=head[u]; i!=-1; i=edge[i].next)
97     {
98         int v=edge[i].to;
99         dfs(v);
100         for (int j=0; j<n-1; j++)
101             SAM_node[u].mat[j]=max(SAM_node[v].mat[j],SAM_node[u].
                mat[j]);
102     }
103     int tmp=SAM_node[u].len;
104     for (int i=0; i<n-1; i++)
105         tmp=min(tmp,SAM_node[u].mat[i]);
106     ans=max(ans,tmp);
107 }
108 int main()
109 {
110
111     while (scanf("%s",s[n])!=EOF)
112         n++;
113     int L=strlen(s[0]);
114     ans=M=0;
115     SAM_build(s[0]);
116     for (int j=1; j<n; j++)
117     {
118         int l=strlen(s[j]),len=0;
119         SAM_Node *p=SAM_root;
120         for (int i=0; i<l; i++)
121         {
122             if (p->next[getid(s[j][i])])
123             {
124                 p=p->next[getid(s[j][i])];
125                 p->mat[j-1]=max(p->mat[j-1],++len);
126             }
127             else
128             {
129                 while (p && !p->next[getid(s[j][i])])
130                     p=p->fa;

```

```

131         if (!p)
132         {
133             p=SAM_root;
134             len=0;
135         }
136         else
137         {
138             len=p->len+1;
139             p=p->next[getid(s[j][i])];
140         }
141         p->mat[j-1]=max(p->mat[j-1],len);
142     }
143 }
144 }
145 memset(head,-1,4*SAM_size);
146 for (int i=1; i<SAM_size; i++)
147     add_edge(SAM_node[i].fa->id,i);
148 dfs(0);
149 printf("%d\n",ans);
150 return 0;
151 }

```

LCS2

```

1  #include <iostream>
2  #include <algorithm>
3  #include <cstdio>
4  #include <cstring>
5  using namespace std;
6
7  const int CHAR = 26;
8  const int MAXN = 100000;
9
10 struct SAM_Node
11 {
12     SAM_Node *fa,*next[CHAR];
13     int len;
14     int id;
15     int mat[9];
16     SAM_Node() {}
17     SAM_Node(int _len)
18     {
19         fa = 0;
20         len = _len;
21         memset(mat,0,sizeof(mat));
22         memset(next,0,sizeof(next));
23     }
24 };
25 SAM_Node SAM_node[MAXN*2],*SAM_root,*SAM_last;
26 int SAM_size;
27 SAM_Node *newSAM_Node(int len)
28 {

```

```

29     SAM_node[SAM_size] = SAM_Node(len);
30     SAM_node[SAM_size].id = SAM_size;
31     return &SAM_node[SAM_size++];
32 }
33 SAM_Node *newSAM_Node(SAM_Node *p)
34 {
35     SAM_node[SAM_size] = *p;
36     SAM_node[SAM_size].id = SAM_size;
37     return &SAM_node[SAM_size++];
38 }
39 void SAM_init()
40 {
41     SAM_size = 0;
42     SAM_root = SAM_last = newSAM_Node(0);
43 }
44 void SAM_add(int x,int len)
45 {
46     SAM_Node *p = SAM_last,*np = newSAM_Node(p->len+1);
47     SAM_last = np;
48     for (; p&&!p->next[x]; p=p->fa)
49         p->next[x] = np;
50     if (!p)
51     {
52         np->fa = SAM_root;
53         return;
54     }
55     SAM_Node *q = p->next[x];
56     if (q->len == p->len+1)
57     {
58         np->fa = q;
59         return;
60     }
61     SAM_Node *nq = newSAM_Node(q);
62     nq->len = p->len+1;
63     q->fa = nq;
64     np->fa = nq;
65     for (; p&&p->next[x] == q; p = p->fa)
66         p->next[x] = nq;
67 }
68 int getid(char ch)
69 {
70     return ch-'a';
71 }
72 void SAM_build(char *s)
73 {
74     SAM_init();
75     int l = strlen(s);
76     for (int i = 0; i < l; i++)
77         SAM_add(getid(s[i]),i+1);
78 }
79 char s[MAXN+1];

```

```

80 int ans;
81 int head[MAXN*2];
82 struct Edge
83 {
84     int to,next;
85 } edge[MAXN*2];
86 int M;
87 int n;
88 void add_edge(int u,int v)
89 {
90     edge[M].to=v;
91     edge[M].next=head[u];
92     head[u]=M++;
93 }
94 void dfs(int u)
95 {
96     for (int i=head[u]; i!=-1; i=edge[i].next)
97     {
98         int v=edge[i].to;
99         /*for (int j=0; j<n; j++)
100             SAM_node[v].mat[j]=max(SAM_node[v].mat[j],SAM_node[u].
                mat[j]);*/
101         dfs(v);
102         for (int j=0; j<n; j++)
103             SAM_node[u].mat[j]=max(SAM_node[v].mat[j],SAM_node[u].
                mat[j]);
104     }
105     int tmp=SAM_node[u].len;
106     for (int i=0; i<n; i++)
107         tmp=min(tmp,SAM_node[u].mat[i]);
108     ans=max(ans,tmp);
109 }
110 int main()
111 {
112     //freopen("in.txt","r",stdin);
113     //freopen("out.txt","w",stdout);
114     n=0;
115     gets(s);
116     SAM_build(s);
117     while (gets(s))
118     {
119         int l=strlen(s),len=0;
120         SAM_Node *p=SAM_root;
121         for (int i=0; i<l; i++)
122         {
123             if (p->next[getid(s[i])])
124             {
125                 p=p->next[getid(s[i])];
126                 p->mat[n]=max(p->mat[n],++len);
127             }
128             else

```

```

129         {
130             while (p && !p->next[getid(s[i])])
131                 p=p->fa;
132             if (!p)
133             {
134                 p=SAM_root;
135                 len=0;
136             }
137             else
138             {
139                 len=p->len+1;
140                 p=p->next[getid(s[i])];
141             }
142             p->mat[n]=max(p->mat[n],len);
143         }
144         //printf("%d %d %d\n",i,len,p->id);
145     }
146     n++;
147 }
148 memset(head,-1,4*SAM_size);
149 for (int i=1; i<SAM_size; i++)
150     add_edge(SAM_node[i].fa->id,i);
151 dfs(0);
152 printf("%d\n",ans);
153 return 0;
154 }

```

3.4 KMP

求A[0..i]的一个后缀最多能匹配B的前缀多长。先对B进行自匹配然后与A匹配。KMP[i]就是对应答案，p[i]+1是B[0..i]的一个后缀最多能匹配B的前缀多长。

```

1 //自匹配过程
2 int j;
3 p[0] = j = -1;
4 for (int i = 1; i < lb; i++)
5 {
6     while (j >= 0 && b[j + 1] != b[i]) j = p[j];
7     if (b[j + 1] == b[i]) j ++;
8     p[i] = j;
9 }
10 //下面是匹配过程
11 j = -1;
12 for (int i = 0; i < la; i++)
13 {
14     while (j >= 0 && b[j + 1] != a[i]) j = p[j];
15     if (b[j + 1] == a[i]) j ++;
16     KMP[i] = j + 1;
17 }

```

3.5 e-KMP

求A[i..len-1]和B的最长公共前缀有多长。先对B进行自匹配然后与A匹配。eKMP[i]就是对应答案。p[i]是B[i..len-1]和B的最长公共前缀有多长。

```

1 //自匹配过程
2 int j = 0;
3 while (j < lb && b[j] == b[j + 1])
4     j++;
5 p[0] = lb, p[1] = j;
6 int k = 1;
7 for (int i = 2; i < lb; i++)
8 {
9     int Len = k + p[k] - 1, L = p[i - k];
10    if (L < Len - i + 1)
11        p[i] = L;
12    else
13    {
14        j = max(0, Len - i + 1);
15        while (i + j < lb && b[i + j] == b[j])
16            j++;
17        p[i] = j, k = i;
18    }
19 }
20 //下面是匹配过程
21 j = 0;
22 while (j < la && j < lb && a[j] == b[j])
23     j++;
24 eKMP[0] = j;
25 k = 0;
26 for (int i = 1; i < la; i++)
27 {
28     int Len = k + eKMP[k] - 1, L = p[i - k];
29     if (L < Len - i + 1)
30         eKMP[i] = L;
31     else
32     {
33         j = max(0, Len - i + 1);
34         while (i + j < la && j < lb && a[i + j] == b[j])
35             j++;
36         eKMP[i] = j, k = i;
37     }
38 }

```

3.6 *Manacher

待整理

```

1 char s[1000], a[3000];
2 int p[3000], len, l, pnow, pid, res, resid;
3
4 int main()
5 {

```



```

6   while (scanf("%s",s) != EOF)
7   {
8       len = strlen(s);
9       l = 0;
10      a[l++] = '.';
11      a[l++] = ',';
12      for (int i = 0;i < len;i++)
13      {
14          a[l++] = s[i];
15          a[l++] = ',';
16      }
17      pnow = 0;
18      res = 0;
19      for (int i = 1;i < l;i++)
20      {
21          if (pnow > i)
22              p[i] = min(p[2*pid-i],pnow-i);
23          else
24              p[i] = 1;
25          for (;a[i-p[i]] == a[i+p[i]];p[i]++);
26          if (i+p[i] > pnow)
27          {
28              pnow = i+p[i];
29              pid = i;
30          }
31          if (p[i] > res)
32          {
33              res = p[i];
34              resid = i;
35          }
36      }
37      for (int i = resid-res+2;i < resid+res-1;i += 2)
38          printf("%c",a[i]);
39      printf("\n");
40  }
41  return 0;
42 }

```

3.7 *字符串最小表示法

```

1  int Gao(char a[],int len)
2  {
3      int i = 0,j = 1,k = 0;
4      while (i < len && j < len && k < len)
5      {
6          int cmp = a[(j+k)%len]-a[(i+k)%len];
7          if (cmp == 0)
8              k++;
9          else
10         {
11             if (cmp > 0)

```

```

12         j += k+1;
13     else
14         i += k+1;
15         if (i == j) j++;
16         k = 0;
17     }
18 }
19 return min(i,j);
20 }

```

3.8 带*通配符的匹配

```

1  #include <iostream>
2  #include <algorithm>
3  #include <cstdio>
4  #include <cstring>
5  using namespace std;
6
7  char a[110],b[110],sp[110][110],tot,place[110];
8  int n,la,lb,ll;
9
10 bool check(int id,int pos)
11 {
12     for (int i = 0;sp[id][i] != 0;i++)
13         if (b[pos+i] != sp[id][i])
14             return false;
15     return true;
16 }
17
18 bool check()
19 {
20     lb = strlen(b);
21     int pre = 0;
22     for (int i = 0;i < tot;i++)
23     {
24         bool find = false;
25         for (int j = pre;j < lb;j++)
26             if (check(i,j) == true)
27             {
28                 place[i] = j;
29                 pre = place[i]+1;
30                 find = true;
31                 break;
32             }
33         if (find == false) return false;
34     }
35     if (a[0] != '*')
36         if (place[0] != 0)
37             return false;
38     if (a[la-1] != '*')
39         if (check(tot-1,lb-1) == false)
40             return false;

```

```
41     return true;
42 }
43
44 int main()
45 {
46     while (scanf("%s",a) != EOF)
47     {
48         tot = 0;
49         for (int i = 0;a[i] != 0;i++)
50             if (a[i] != '*')
51             {
52                 int j;
53                 for (j = i;a[j] != 0 && a[j] != '*';j++)
54                     sp[tot][j-i] = a[j];
55                 sp[tot++][j-i] = 0;
56                 i = j;
57             }
58         la = strlen(a);
59         ll = strlen(sp[tot-1]);
60         scanf("%d",&n);
61         for (int i = 0;i < n;i++)
62         {
63             scanf("%s",b);
64             if (check() == true)
65                 puts(b);
66         }
67     }
68     return 0;
69 }
70 /*
71 Sample Input 1
72 *.*
73 4
74 main.c
75 a.out
76 readme
77 yacc
78
79 Sample Input 2
80 *a*a*a
81 4
82 aaa
83 aaaaa
84 aaaaax
85 abababa
86
87 Sample Output 1
88 main.c
89 a.out
90
91 Sample Output 2
```

```
92 | aaa
93 | aaaaa
94 | abababa
95 | */
```

4 数学

4.1 扩展GCD

求 $ax+by=\gcd(a,b)$ 的一组解

```

1 long long ex_gcd(long long a,long long b,long long &x,long long &y)
2 {
3     if (b)
4     {
5         long long ret = ex_gcd(b,a%b,x,y),tmp = x;
6         x = y;
7         y = tmp-(a/b)*y;
8         return ret;
9     }
10    else
11    {
12        x = 1;
13        y = 0;
14        return a;
15    }
16 }
```

4.2 模线性方程组

```

1 //有更新
2 int m[10],a[10]; //模数m 余数a
3 bool solve(int &m0,int &a0,int m,int a) //模线性方程组
4 {
5     int y,x;
6     int g=ex_gcd(m0,m,x,y);
7     if (abs(a-a0)%g) return 0;
8     x*=(a-a0)/g;
9     x%=m/g;
10    a0=(x*m0+a0);
11    m0*=m/g;
12    a0%=m0;
13    if (a0<0) a0+=m0;
14    return 1;
15 }
16 int MLES()
17 {
18     bool flag=1;
19     int m0=1,a0=0;
20     for (int i=0; i<n; i++)
21         if (!solve(m0,a0,m[i],a[i]))
22         {
23             flag=0;
24             break;
25         }
26     if (flag)
```

```

27     return a0;
28     else
29         return -1;
30 }

```

4.3 矩阵

乘法的时候将 B 数组转置一下然后 $C[i][j] = \sum A[i][k] \times B[j][k]$ 会有奇效。

```

1 struct Matrix
2 {
3     int a[52][52];
4     Matrix operator * (const Matrix &b) const
5     {
6         Matrix res;
7         for (int i = 0; i < 52; i++)
8             for (int j = 0; j < 52; j++)
9                 {
10                     res.a[i][j] = 0;
11                     for (int k = 0; k < 52; k++)
12                         res.a[i][j] += a[i][k] * b.a[k][j];
13                 }
14         return res;
15     }
16     Matrix operator ^ (int y) const
17     {
18         Matrix res, x;
19         for (int i = 0; i < 52; i++)
20             {
21                 for (int j = 0; j < 52; j++)
22                     res.a[i][j] = 0, x.a[i][j] = a[i][j];
23                 res.a[i][i] = 1;
24             }
25         for (; y; y >>= 1, x = x * x)
26             if (y & 1)
27                 res = res * x;
28         return res;
29     }
30 };

```

4.4 康拓展开

```

1 const int PermSize = 12;
2 int factory[PermSize] = {1, 1, 2, 6, 24, 120, 720, 5040, 40320,
3     362880, 3628800, 39916800};
4 int Cantor(int a[])
5 {
6     int i, j, counted;
7     int result = 0;
8     for (i = 0; i < PermSize; ++i)
9     {
10         counted = 0;

```

```

10         for (j = i + 1; j < PermSize; ++j)
11             if (a[i] > a[j])
12                 ++counted;
13         result = result + counted * factory[PermSize - i - 1];
14     }
15     return result;
16 }
17
18 bool h[13];
19
20 void UnCantor(int x, int res[])
21 {
22     int i,j,l,t;
23     for (i = 1;i <= 12;i++)
24         h[i] = false;
25     for (i = 1; i <= 12; i++)
26     {
27         t = x / factory[12 - i];
28         x -= t * factory[12 - i];
29         for (j = 1, l = 0; l <= t; j++)
30             if (!h[j])l++;
31         j--;
32         h[j] = true;
33         res[i - 1] = j;
34     }
35 }

```

4.5 FFT

```

1  const double PI= acos(-1.0);
2  struct vir
3  {
4      double re,im; //实部和虚部
5      vir(double a=0,double b=0)
6      {
7          re=a;
8          im=b;
9      }
10     vir operator +(const vir &b)
11     {return vir(re+b.re,im+b.im);}
12     vir operator -(const vir &b)
13     {return vir(re-b.re, im-b.im);}
14     vir operator *(const vir &b)
15     {return vir(re*b.re-im*b.im , re*b.im+im*b.re);}
16 };
17 vir x1[200005],x2[200005];
18 void change(vir *x,int len,int loglen)
19 {
20     int i,j,k,t;
21     for(i=0;i<len;i++)
22     {
23         t=i;

```

```

24     for(j=k=0; j<loglen; j++,t>>=1)
25         k= (k<<1)|(t&1);
26     if(k<i)
27     {
28         // printf("%d %d\n",k,i);
29         vir wt=x[k];
30         x[k]=x[i];
31         x[i]=wt;
32     }
33 }
34 }
35 void fft(vir *x,int len,int loglen)
36 {
37     int i,j,t,s,e;
38     change(x,len,loglen);
39     t=1;
40     for(i=0;i<loglen;i++,t<=&1)
41     {
42         s=0;
43         e=s+t;
44         while(s<len)
45         {
46             vir a,b,wo(cos(PI/t),sin(PI/t)),wn(1,0);
47             for(j=s;j<s+t;j++)
48             {
49                 a=x[j];
50                 b=x[j+t]*wn;
51                 x[j]=a+b;
52                 x[j+t]=a-b;
53                 wn=wn*wo;
54             }
55             s=e+t;
56             e=s+t;
57         }
58     }
59 }
60 void dit_fft(vir *x,int len,int loglen)
61 {
62     int i,j,s,e,t=1<<loglen;
63     for(i=0;i<loglen;i++)
64     {
65         t>>=1;
66         s=0;
67         e=s+t;
68         while(s<len)
69         {
70             vir a,b,wn(1,0),wo(cos(PI/t),-sin(PI/t));
71             for(j=s;j<s+t;j++)
72             {
73                 a=x[j]+x[j+t];
74                 b=(x[j]-x[j+t])*wn;

```



```

75     x[j]=a;
76     x[j+t]=b;
77     wn=wn*wo;
78 }
79 s=e+t;
80 e=s+t;
81 }
82 }
83 change(x,len,loglen);
84 for(i=0;i<len;i++)
85     x[i].re/=len;
86 }
87 int main()
88 {
89     char a[100005],b[100005];
90     int i,len1,len2,len,loglen;
91     int t,over;
92     while(scanf("%s%s",a,b)!=EOF)
93     {
94         len1=strlen(a)<<1;
95         len2=strlen(b)<<1;
96         len=1;loglen=0;
97         while(len<len1)
98         {
99             len<<=1;    loglen++;
100        }
101        while(len<len2)
102        {
103            len<<=1;    loglen++;
104        }
105        for(i=0;a[i];i++)
106        {
107            x1[i].re=a[i]-'0';
108            x1[i].im=0;
109        }
110        for(;i<len;i++)
111            x1[i].re=x1[i].im=0;
112        for(i=0;b[i];i++)
113        {
114            x2[i].re=b[i]-'0';
115            x2[i].im=0;
116        }
117        for(;i<len;i++)
118            x2[i].re=x2[i].im=0;
119        fft(x1,len,loglen);
120        fft(x2,len,loglen);
121        for(i=0;i<len;i++)
122            x1[i] = x1[i]*x2[i];
123        dit_fft(x1,len,loglen);
124        for(i=(len1+len2)/2-2,over=len=0;i>=0;i--)
125        {

```

```

126     t=(int)(x1[i].re+over+0.5);
127     a[len++]= t%10;
128     over = t/10;
129 }
130 while(over)
131 {
132     a[len++]=over%10;
133     over/=10;
134 }
135 for(len--;len>=0&&!a[len];len--);
136 if(len<0)
137     putchar('0');
138 else
139     for(;len>=0;len--)
140         putchar(a[len]+'0');
141     putchar('\n');
142 }
143 return 0;
144 }

```

4.6 爬山法计算器

注意灵活运用。

双目运算符在calc()中，左结合单目运算符在P()中，右结合单目运算符在calc_exp中。（但是还没遇到过。。）

```

1  #include <iostream>
2  #include <cstdio>
3  #include <cstring>
4  #include <algorithm>
5  #include <string>
6  using namespace std;
7
8  char s[100000];
9  int n,cur;
10 const string OP = "+- *";
11
12 char next_char()
13 {
14     if (cur >= n) return EOF;
15     return s[cur];
16 }
17
18 int get_priority(char ch)
19 {
20     if (ch == '*') return 2;
21     return 1;
22 }
23
24 int P();
25
26 int calc(int a,char op,int b)

```

```

27 {
28     if (op == '+')
29         return a+b;
30     if (op == '-')
31         return a-b;
32     if (op == '*')
33         return a*b;
34 }
35
36 int calc_exp(int p)
37 {
38     int a = P();
39     while ((OP.find(next_char()) != OP.npos) && (get_priority(
40         next_char()) >= p))
41     {
42         char op = next_char();
43         cur++;
44         a = calc(a,op,calc_exp(get_priority(op)+1));
45     }
46     return a;
47 }
48 int totvar,m,var[26],varid[26];
49
50 int P()
51 {
52     if (next_char() == '-')
53     {
54         cur++;
55         return -P();
56     }
57     else if (next_char() == '+')
58     {
59         cur++;
60         return P();
61     }
62     else if (next_char() == '(')
63     {
64         cur++;
65         int res = calc_exp(0);
66         cur++;
67         return res;
68     }
69     else
70     {
71         cur++;
72         //cout << "getvar at " << cur << ' ' << var[varid[s[cur]-'a'
73             ']] << endl;
74         return var[varid[s[cur-1]-'a']];
75     }
76 }

```

```
76
77 int id[26],minid;
78
79 int main()
80 {
81     while (true)
82     {
83         scanf("%d%d",&totvar,&var[0]);
84         if (totvar == 0 && var[0] == 0) break;
85         for (int i = 1;i < totvar;i++)
86             scanf("%d",&var[i]);
87         scanf("%d",&m);
88         scanf("%s",s);
89         for (int i = 0;i < 26;i++)
90             id[i] = -1;
91         minid = 0;
92         n = strlen(s);
93         for (int i = 0;i < n;i++)
94             if (s[i] >= 'a' && s[i] <= 'z')
95             {
96                 if (id[s[i]-'a'] == -1)
97                 {
98                     id[s[i]-'a'] = minid;
99                     minid++;
100                 }
101                 s[i] = 'a'+id[s[i]-'a'];
102             }
103         for (int i = 0;i < totvar;i++)
104             varid[i] = i;
105         int res = 0;
106         do
107         {
108             cur = 0;
109             int tmp = calc_exp(0);
110             if (tmp == m)
111             {
112                 res++;
113                 break;
114             }
115         }
116         while (next_permutation(varid,varid+totvar));
117         //puts(s);
118         if (res > 0)
119             puts("YES");
120         else
121             puts("NO");
122     }
123     return 0;
124 }
```

4.7 线性筛

```

1 int N;
2 bool isPrime[10001];
3 int prime[10000];
4 void getPrime(int n)
5 {
6     memset(isPrime,1,++n);
7     N=0;
8     isPrime[0]=isPrime[1]=0;
9     for (int i=2;i<n;i++)
10     {
11         if (isPrime[i])
12             prime[N++]=i;
13         for (int j=0;j<N && prime[j]*i<n;j++)
14         {
15             isPrime[i*prime[j]]=0;
16             if (i%prime[j]==0)
17                 break;
18         }
19     }
20 }

```

4.8 线性规划

```

1 #define MAXM 20 //max num of basic variables
2 #define INF 1E200
3
4 double A[MAXM+5][MAXN+MAXM+5];
5 double b[MAXM+5],c[MAXN+MAXM+5];
6 int N[MAXN+5],B[MAXM+5];
7 double X[MAXN+MAXM+5],V;
8 int n,m,R,C,nCnt,bCnt;
9 int v1[MAXN],v2[MAXN];
10
11 int fcmp(double a,double b)
12 {
13     if(fabs(a-b)<1E-7) return 0;
14     if(a>b) return 1;
15     return -1;
16 }
17
18 void Pivot(int l,int e)
19 {
20     double t=A[l][e],p=c[e];
21     b[l]=b[l]/t;
22     for(int i=1;i<=C;i++)
23         A[l][i]/=t;
24     V=V-c[e]*b[l];
25     for(int i=1;i<=R;i++)
26     {
27         if(i==l || fcmp(A[i][e],0.0)==0)

```

```

28     continue;
29     t=A[i][e];
30     b[i]=b[i]-t*b[l];
31     for(int j=1;j<=C;j++)
32         A[i][j]=A[i][j]-t*A[l][j];
33 }
34 for(int i=1;i<=C;i++)
35     c[i]=c[i]-p*A[l][i];
36 for(int i=1;i<=nCnt;i++)
37 {
38     if(N[i]==e)
39     {
40         N[i]=B[l];
41         break;
42     }
43 }
44 B[l]=e;
45 }
46
47 bool Process(double P[])
48 {
49     while(true)
50     {
51         int e=-1;
52         double mV=-INF;
53         for(int i=1;i<=nCnt;i++)
54             if(fcmp(P[N[i]],mV)==1)
55                 mV=P[N[i]],e=N[i];
56
57         if(fcmp(mV,0.0)<=0) break;
58         int l=-1;
59         mV=INF;
60         for(int i=1;i<=bCnt;i++)
61         {
62             if(fcmp(A[i][e],0.0)==1)
63             {
64                 double t=b[i]/A[i][e];
65                 if(fcmp(mV,t)==1||(fcmp(mV,t)==0&&(l==-1||B[l]>B[i])))
66                     mV=t,l=i;
67             }
68         }
69         if(l==-1) return false;
70         Pivot(l,e);
71     }
72     return true;
73 }
74
75 bool initSimplex()
76 {
77     nCnt=bCnt=0;
78     for(int i=1;i<=n;i++)

```

```

79     N[++nCnt]=i;
80     for(int i=1;i<=m;i++)
81         B[++bCnt]=i+n,A[i][n+i]=1.0;
82     R=bCnt,C=bCnt+nCnt;
83     double minV=INF;
84     int p=-1;
85     for(int i=1;i<=m;i++)
86         if(fcmp(minV,b[i])==1)
87             minV=b[i],p=i;
88     if(fcmp(minV,0.0)>=0)
89         return true;
90     N[++nCnt]=n+m+1;R++,C++;
91     for(int i=0;i<=C;i++)
92         A[R][i]=0.0;
93     for(int i=1;i<=R;i++)
94         A[i][n+m+1]=-1.0;
95     Pivot(p,n+m+1);
96     if(!Process(A[R])) return false;
97     if(fcmp(b[R],0.0)!=0)
98         return false;
99     p=-1;
100    for(int i=1;i<=bCnt&& p==-1;i++)
101        if(B[i]==n+m+1) p=i;
102    if(p!=-1)
103    {
104        for(int i=1;i<=nCnt;i++)
105        {
106            if(fcmp(A[p][N[i]],0.0)!=0)
107            {
108                Pivot(p,N[i]);
109                break;
110            }
111        }
112    }
113    bool f=false;
114    for(int i=1;i<=nCnt;i++)
115    {
116        if(N[i]==n+m+1) f=true;
117        if(f&& i+1<=nCnt)
118            N[i]=N[i+1];
119    }
120    nCnt--;
121    R--,C--;
122    return true;
123 }
124
125 //-1: no solution 1: no bound 0: has a solution -V
126 int Simplex()
127 {
128     if(!initSimplex())
129         return -1;

```

```

130     if(!Process(c))
131         return 1;
132     for(int i=1;i<=nCnt;i++)
133         X[N[i]]=0.0;
134     for(int i=1;i<=bCnt;i++)
135         X[B[i]]=b[i];
136     return 0;
137 }
138
139 int main()
140 {
141     //n = 1;m=1;
142     //V= 0.0;
143     //c[1] = 1.0;
144     //A[1][1] = 1.0;
145     //b[1] = 5.0;
146     //Simplex();
147     //printf("V = %.3f\n",V);
148
149     while(scanf("%d",&v1[1]) == 1)
150     {
151         for(int i = 2; i<=6;i++)
152             scanf("%d",&v1[i]);
153         n = 4; m = 6;
154         for(int i = 0 ; i<=m+1;i++)
155             for(int j=0;j<=n+m+2;j++)
156                 A[i][j] = c[j] = 0;
157         memset(b,0,sizeof(b));
158         V = 0.0;
159         /*
160         n 为未知数个数
161         m 为约束个数
162         目标: siama(c[i]*xi)
163         约束: sigma(A[i][j]*xj) <=b[i]; j = 1 ... n
164         解存在X里面
165         */
166         b[1] = v1[1] ; A[1][1] = 1;A[1][4] = 1;
167         b[2] = v1[2] ; A[2][1] = 1;A[2][3] = 1;
168         b[3] = v1[3] ; A[3][3] = 1;A[3][4] = 1;
169         b[4] = v1[4] ; A[4][2] = 1;A[4][3] = 1;
170         b[5] = v1[5] ; A[5][2] = 1;A[5][4] = 1;
171         b[6] = v1[6] ; A[6][1] = 1;A[6][2] = 1;
172         c[1] = 1;c[2] = 1;c[3] = 1;c[4] = 1;
173         Simplex();
174         //printf("V = %.3f\n",V);
175         printf("%.3f□%.3f□%.3f□%.3f\n",X[1],X[2],X[3],X[4]);
176
177     }
178     return 0;
179 }

```


4.9 分解质因数

4.9.1 米勒拉宾+分解因数

```

1  #include<ctime>
2  #include<iostream>
3  #define bint long long
4  using namespace std;
5  const int TIME = 8;//测试次数, 够了8~10
6  int factor[100], fac_top = -1;
7
8  //计算两个数的gcd
9  bint gcd(bint small, bint big)
10 {
11     while(small)
12     {
13         swap(small, big);
14         small%=big;
15     }
16     return abs(big);
17 }
18
19 //ret = (a*b)%n (n<2^62)
20 bint muti_mod(bint a, bint b, bint n)
21 {
22     bint exp = a%n, res = 0;
23     while(b)
24     {
25         if(b&1)
26         {
27             res += exp;
28             if(res>n) res -= n;
29         }
30         exp <<= 1;
31         if (exp>n) exp -= n;
32         b>>=1;
33     }
34     return res;
35 }
36
37 // ret = (a^b)%n
38 bint mod_exp(bint a, bint p, bint m)
39 {
40     bint exp=a%m, res=1; //
41     while(p>1)
42     {
43         if(p&1)
44             res=muti_mod(res, exp, m);
45         exp = muti_mod(exp, exp, m);
46         p>>=1;
47     }
48     return muti_mod(res, exp, m);

```

```

49 }
50
51 //miller-法测试素数rabin, time 测试次数
52 bool miller_rabin(bint n, int times)
53 {
54     if(n==2)return 1;
55     if(n<2||!(n&1))return 0;
56     bint a, u=n-1, x, y;
57     int t=0;
58     while(u%2==0)
59     {
60         t++;
61         u/=2;
62     }
63     srand(time(0));
64     for(int i=0; i<times; i++)
65     {
66         a = rand() % (n-1) + 1;
67         x = mod_exp(a, u, n);
68         for(int j=0; j<t; j++)
69         {
70             y = muti_mod(x, x, n);
71             if ( y == 1 && x != 1 && x != n-1 )
72                 return false; //must not
73             x = y;
74         }
75         if( y!=1) return false;
76     }
77     return true;
78 }
79
80 bint pollard_rho(bint n,int c)//找出一个因子
81 {
82     bint x,y,d,i = 1,k = 2;
83     srand(time(0));
84     x = rand()%(n-1)+1;
85     y = x;
86     while(true)
87     {
88         i++;
89         x = (muti_mod(x,x,n) + c) % n;
90         d = gcd(y-x, n);
91         if (1 < d && d < n) return d;
92         if( y == x) return n;
93         if(i == k)
94         {
95             y = x;
96             k <<= 1;
97         }
98     }
99 }

```

```

100 |
101 | void findFactor(bint n,int k)//二分找出所有质因子, 存入factor
102 | {
103 |     if(n==1)return;
104 |     if(miller_rabin(n, TIME))
105 |     {
106 |         factor[++fac_top] = n;
107 |         return;
108 |     }
109 |     bint p = n;
110 |     while(p >= n)
111 |         p = pollard_rho(p,k--); //值变化, 防止死循环k
112 |     findFactor(p,k);
113 |     findFactor(n/p,k);
114 | }
115 |
116 | int main()
117 | {
118 |     bint cs,n,min;
119 |     cin>>cs;
120 |     while (cs--)
121 |     {
122 |         cin>>n;
123 |         fac_top = min = -1;
124 |         if(miller_rabin(n,TIME)) cout<<"Prime"<<endl;
125 |         else
126 |         {
127 |             findFactor(n,107);
128 |             for(int i=0; i<=fac_top; i++)
129 |             {
130 |                 if(min<0||factor[i]<min)
131 |                     min = factor[i];
132 |             }
133 |             cout<<min<<endl;
134 |         }
135 |     }
136 |     return 0;
137 | }

```

4.9.2 暴力版本

```

1 | int N;
2 | int num[30],fac[30];
3 | void getFactor(int x)
4 | {
5 |     N=0;
6 |     memset(num,0,sizeof(num));
7 |     for (int i=0; prime[i]*prime[i]<=x && i<L; i++)
8 |     {
9 |         if (x%prime[i]==0)
10 |         {
11 |             while (x%prime[i]==0)

```

```

12         {
13             x/=prime[i];
14             num[N]++;
15         }
16         fac[N++]=prime[i];
17     }
18 }
19 if (x>1)
20 {
21     num[N]=1;
22     fac[N++]=x;
23 }
24 }

```

4.10 baby step giant step

```

1 #define MOD 76543
2 int hs[MOD], head[MOD], next[MOD], id[MOD], top;
3 void insert(int x, int y)
4 {
5     int k = x%MOD;
6     hs[top] = x, id[top] = y, next[top] = head[k], head[k] = top++;
7 }
8 int find(int x)
9 {
10     int k = x%MOD;
11     for (int i = head[k]; i; i = next[i]) if (hs[i] == x) return id
        [i];
12     return -1;
13 }
14 int BSGS(int a, int b, int n)
15 {
16     memset(head, 0, sizeof(head));
17     top = 1;
18     if (b==1) return 0;
19     int m = sqrt(n+.0), j;
20     long long x = 1, p = 1;
21     for (int i = 0; i < m; ++i, p = p*a%n) insert(p*b%n, i);
22     for (long long i = m; ; i += m)
23     {
24         if ((j = find(x=x*p%n)) != -1) return i-j;
25         if (i > n) break;
26     }
27     return -1;
28 }

```

4.11 原根

```

1 int getPriRoot(int p)
2 {
3     if (p==2) return 1;
4     int phi = p - 1;

```

```

5   getFactor(phi);
6   for (int g = 2; g < p; ++g)
7   {
8       bool flag=1;
9       for (int i = 0; flag && i < N; ++i)
10          if (power(g, phi/fac[i], p) == 1)
11             flag=0;
12       if (flag)
13          return g;
14   }
15 }

```

4.12 逆元

```

1 void getInv2(int x)
2 {
3     inv[1]=1;
4     for (int i=2; i<=x; i++)
5         inv[i]=(mod-(mod/i)*inv[mod%i]%mod)%mod;
6 }
7 int getInv(int x)//为素数mod
8 {
9     return power(x,mod-2);
10 }

```

4.13 卢卡斯

卢卡斯, $num[i]$ 阶乘也

```

1 int comLucus(int n,int m,int p)
2 {
3     int ans=1;
4     for (; n && m && ans; n/=p,m/=p)
5     {
6         if (n%p>=m%p)
7             ans = ans*num[n%p]%p*getInv(num[m%p]%p)%p*getInv(num[n%
8                 p-m%p])%p;
9         else
10            ans=0;
11    }
12    return ans;
13 }

```

4.14 欧拉函数

4.14.1 分解质因数

```

1 int getEuler(int x)
2 {
3     getFactor(x);
4     int ret=x;
5     for (int i=0; i<N; i++)
6         ret = ret/fac[i]*(fac[i]-1);

```

```

7     return ret;
8 }

```

4.14.2 一次预处理

```

1 void getEuler2()
2 {
3     memset(euler,0,sizeof(euler));
4     euler[1] = 1;
5     for (int i = 2; i <= 3000000; i++)
6     {
7         if (!euler[i])
8         {
9             for (int j = i; j <= 3000000; j += i)
10            {
11                if (!euler[j])
12                    euler[j] = j;
13                euler[j] = euler[j]/i*(i-1);
14            }
15        }
16    }
17 }

```

4.15 费马降阶法

分解素数 p 为 $x^2 + y^2$ 的费马降阶法，失败返回-1，主程序调用calcu(p,x,y)

```

1 #include <stdio.h>
2 #include <string.h>
3 #include <stdlib.h>
4 int p,expp,A,B,aa,ans,tt;
5 long long M;
6 long long exp(int a,int b,long long mod)
7 {
8     long long ans=1,num=a;
9     while (b!=0)
10    {
11        if (b&1)
12        {
13            ans=((ans%mod)*(num%mod))%mod;
14        }
15        num=((num%mod)*(num%mod))%mod;
16        b>>=1;
17    }
18    return ans;
19 }
20 int calcu(int p,int &x,int &y)
21 {
22     if (p%4!=1) return -1;
23     else
24     {
25         expp=(p-1)/4;
26         A,B;

```

```

27         while (1)
28         {
29             aa=rand()%p;
30             if (aa==0) continue;
31             A=exp(aa,exp,p);
32             ans=((long long)A%p)*((long long)A%p)%p;
33             if (ans==p-1) break;
34         }
35         B=1;
36         M=((long long)A*(long long)A+(long long)B*(long long)
           B)/p;
37         if (M!=1) B=p;
38         while (M!=1)
39         {
40             if (B>A)
41             {tt=A; A=B; B=tt;}
42             tt=A;
43             A=B;
44             B=tt%B;
45             M=((long long)A*(long long)A+(long long)B*(long
           long)B)/p;
46         }
47         if (B<=A)
48         {
49             x=B;
50             y=A;
51         }
52         else
53         {
54             x=A;
55             y=B;
56         }
57     }
58 }
59 int main()
60 {
61     while (scanf("%d",&p)!=EOF)
62     {
63         int x,y;
64         if (calcu(p,x,y)!=-1)
65         {
66             return 0;
67         }

```

4.16 自适应simp

过了哈尔滨积分题，精度要求不高的时候可以考虑使用。
暂时我只能用这个做做类似于凸函数或者凹函数的函数。

```

1 double Simp(double l,double r)
2 {
3     double h = (r-l)/2.0;

```

```

4     return h*(calc(l)+4*calc((l+r)/2.0)+calc(r))/3.0;
5 }
6
7 double rSimp(double l,double r)
8 {
9     double mid = (l+r)/2.0;
10    if (abs((Simp(l,r)-Simp(l,mid)-Simp(mid,r)))/15 < eps)
11        return Simp(l,r);
12    else
13        return rSimp(l,mid)+rSimp(mid,r);
14 }

```

4.17 组合数求模

模是质数

```

1  #include<cstdio>
2  #include<cstring>
3  #include<iostream>
4  using namespace std;
5  int mod;
6  long long num[100000];
7  int ni[100],mi[100];
8  int len;
9  void init(int p)
10 {
11     mod=p;
12     num[0]=1;
13     for (int i=1; i<p; i++)
14         num[i]=i*num[i-1]%p;
15 }
16 void get(int n,int ni[],int p)
17 {
18     for (int i = 0; i < 100; i++)
19         ni[i] = 0;
20     int tlen = 0;
21     while (n != 0)
22     {
23         ni[tlen++] = n%p;
24         n /= p;
25     }
26     len = tlen;
27 }
28 long long power(long long x,long long y)
29 {
30     long long ret=1;
31     for (long long a=x%mod; y; y>>=1,a=a*a%mod)
32         if (y&1)
33             ret=ret*a%mod;
34     return ret;
35 }
36 long long getInv(long long x)//mod为素数

```



```

37 {
38     return power(x,mod-2);
39 }
40 long long calc(int n,int m,int p)//C(n,m)%p
41 {
42     init(p);
43     long long ans=1;
44     for (; n && m && ans; n/=p,m/=p)
45     {
46         if (n%p>=m%p)
47             ans = ans*num[n%p]%p*getInv(num[m%p]%p)%p*getInv(num[n%
48                 p-m%p])%p;
49         else
50             ans=0;
51     }
52     return ans;
53 }
54 int main()
55 {
56     int t;
57     scanf("%d",&t);
58     while (t--)
59     {
60         int n,m,p;
61         scanf("%d%d%d",&n,&m,&p);
62         printf("%I64d\n",calc(n+m,m,p));
63     }
64     return 0;
65 }

```

4.18 其它公式

4.18.1 拉格朗日插值法

已知 $y = a_0 + a_1x + a_2x^2 + \cdots + a_{n-1}x^{n-1}$ 曲线上的 n 个点 $(x_1, y_1), (x_2, y_2), (x_3, y_3) \cdots (x_n, y_n)$ 用拉格朗日插值法可以不求系数可知任意 x 对应的 y 值。

$$\begin{aligned}
 y = & y_1 \frac{(x-x_2)(x-x_3) \cdots (x-x_n)}{(x_1-x_2)(x_1-x_3) \cdots (x_1-x_n)} \\
 & + y_2 \frac{(x-x_1)(x-x_3) \cdots (x-x_n)}{(x_2-x_1)(x_2-x_3) \cdots (x_2-x_n)} \\
 & + \cdots \\
 & + y_n \frac{(x-x_1)(x-x_2) \cdots (x-x_{n-1})}{(x_n-x_1)(x_n-x_2) \cdots (x_n-x_{n-1})}
 \end{aligned}$$

特别的，如果 $x_1 \sim x_n$ 为连续自然数，那么对于下一个自然数对应的 y 值为：

$$y_{n+1} = (-1)^{n-1}C_n^0 y_1 + (-1)^{n-2}C_n^1 y_2 + \cdots + (-1)^0 C_n^{n-1} y_n$$

这个组合系数可以通过高斯消元求出来，前提是要猜到它满足递推关系。

4.18.2 正多面体顶点着色

正四面体: $N = \frac{(n^4+11 \times n^2)}{12}$

正六面体: $N = \frac{(n^8+17 \times n^4+6 \times n^2)}{24}$

正八面体: $N = \frac{(n^6+3 \times n^4+12 \times n^3+8 \times n^2)}{24}$

正十二面体: $N = \frac{(n^{20}+15 \times n^{10}+20 \times n^8+24 \times n^4)}{60}$

正二十面体: $N = \frac{(n^{12}+15 \times n^6+44 \times n^4)}{60}$

4.18.3 求和公式

$$\sum k = \frac{n \times (n+1)}{2}$$

$$\sum 2k - 1 = n^2$$

$$\sum k^2 = \frac{n \times (n+1) \times (2n+1)}{6}$$

$$\sum (2k-1)^2 = \frac{n \times (4n^2-1)}{3}$$

$$\sum k^3 = \left(\frac{n \times (n+1)}{2}\right)^2$$

$$\sum (2k-1)^3 = n^2 \times (2n^2-1)$$

$$\sum k^4 = \frac{n \times (n+1) \times (2n+1) \times (3n^2+3n-1)}{30}$$

$$\sum k^5 = \frac{n^2 \times (n+1)^2 \times (2n^2+2n-1)}{12}$$

$$\sum k \times (k+1) = \frac{n \times (n+1) \times (n+2)}{3}$$

$$\sum k \times (k+1) \times (k+2) = \frac{n \times (n+1) \times (n+2) \times (n+3)}{4}$$

$$\sum k \times (k+1) \times (k+2) \times (k+3) = \frac{n \times (n+1) \times (n+2) \times (n+3) \times (n+4)}{5}$$

4.18.4 几何公式

球扇形:

全面积: $T = \pi r(2h + r_0)$, h 为球冠高, r_0 为球冠底面半径

体积: $V = \frac{2\pi r^2 h}{3}$

4.18.5 小公式

Pick 公式: $A = E \times 0.5 + I - 1$ (A 是多边形面积, E 是边界上的整点, I 是多边形内部的整点)

海伦公式: $S = \sqrt{p(p-a)(p-b)(p-c)}$, 其中 $p = \frac{(a+b+c)}{2}$, abc 为三角形的三条边长

求 $\binom{n}{k}$ 中素因子 P 的个数:

1. 把 n 转化为 P 进制, 并记它每个位上的和为 $S1$

2. 把 $n-k$, k 做同样的处理, 得到 $S2$, $S3$

则 $\binom{n}{k}$ 中素因子 P 的个数: $\frac{S2+S3-S1}{P-1}$

部分错排公式:

$n+m$ 个数中 m 个数必须错排 求排列数

```
1 | dp[i] = n*dp[i-1] + (i-1)*(dp[i-1] + dp[i-2]);
2 | dp[0] = n!;
3 | dp[1] = n*n!;
```

$dp[m]$ 为所求解

5 数据结构

5.1 *Splay

持续学习中。

注意节点的size值不一定是真实的值！如果有需要需要特别维护！

1. 旋转和Splay操作
2. rank操作
3. insert操作（。。很多题目都有）
4. del操作（郁闷的出纳员）
5. 由数组建立Splay
6. 前驱后继（营业额统计）
7. Pushdown Pushup的位置
8. *。。。暂时想不起了

节点定义。。

```

1  const int MaxN = 50003;
2
3  struct Node
4  {
5      int size, key;
6
7      Node *c[2];
8      Node *p;
9  } mem[MaxN], *cur, *nil;
```

无内存池的几个初始化函数。

```

1  Node *newNode(int v, Node *p)
2  {
3      cur->c[0] = cur->c[1] = nil, cur->p = p;
4      cur->size = 1;
5      cur->key = v;
6      return cur++;
7  }
8
9  void Init()
10 {
11     cur = mem;
12     nil = newNode(0, cur);
13     nil->size = 0;
14 }
```

带内存池的几个函数。

```

1 int emp[MaxN], totemp;
2
3 Node *newNode(int v, Node *p)
4 {
5     cur = mem + emp[--totemp];
6     cur->c[0] = cur->c[1] = nil, cur->p = p;
7     cur->size = 1;
8     cur->key = v;
9     return cur;
10 }
11
12 void Init()
13 {
14     for (int i = 0; i < MaxN; ++i)
15         emp[i] = i;
16     totemp = MaxN;
17     cur = mem + emp[--totemp];
18     nil = newNode(0, cur);
19     nil->size = 0;
20 }
21
22 void Recycle(Node *p)
23 {
24     if (p == nil) return;
25     Recycle(p->c[0]), Recycle(p->c[1]);
26     emp[totemp++] = p - mem;
27 }

```

基本的Splay框架。维护序列用。
一切下标从0开始。

```

1 struct SplayTree
2 {
3     Node *root;
4     void Init()
5     {
6         root = nil;
7     }
8     void Pushup(Node *x)
9     {
10         if (x == nil) return;
11         Pushdown(x); Pushdown(x->c[0]); Pushdown(x->c[1]);
12         x->size = x->c[0]->size + x->c[1]->size + 1;
13     }
14     void Pushdown(Node *x)
15     {
16         if (x == nil) return;
17         //do something
18     }
19     void Rotate(Node *x, int f)
20     {

```

```

21     if (x == nil)    return;
22     Node *y = x->p;
23     y->c[f ^ 1] = x->c[f], x->p = y->p;
24     if (x->c[f] != nil)
25         x->c[f]->p = y;
26     if (y->p != nil)
27         y->p->c[y->p->c[1] == y] = x;
28     x->c[f] = y, y->p = x;
29     Pushup(y);
30 }
31 void Splay(Node *x, Node *f)
32 {
33     while (x->p != f)
34     {
35         Node *y = x->p;
36         if (y->p == f)
37             Rotate(x, x == y->c[0]);
38         else
39         {
40             int fd = y->p->c[0] == y;
41             if (y->c[fd] == x)
42                 Rotate(x, fd ^ 1), Rotate(x, fd);
43             else
44                 Rotate(y, fd), Rotate(x, fd);
45         }
46     }
47     Pushup(x);
48     if (f == nil)
49         root = x;
50 }
51 void Select(int k, Node *f)
52 {
53     Node *x = root;
54     Pushdown(x);
55     int tmp;
56     while ((tmp = x->c[0]->size) != k)
57     {
58         if (k < tmp)    x = x->c[0];
59         else
60             x = x->c[1], k -= tmp + 1;
61         Pushdown(x);
62     }
63     Splay(x, f);
64 }
65 void Select(int l, int r)
66 {
67     Select(l, nil), Select(r + 2, root);
68 }
69 Node *Make_tree(int a[], int l, int r, Node *p)
70 {
71     if (l > r)    return nil;

```

```

72     int mid = l + r >> 1;
73     Node *x = newNode(a[mid], p);
74     x->c[0] = Make_tree(a, l, mid - 1, x);
75     x->c[1] = Make_tree(a, mid + 1, r, x);
76     Pushup(x);
77     return x;
78 }
79 void Insert(int pos, int a[], int n)
80 {
81     Select(pos, nil), Select(pos + 1, root);
82     root->c[1]->c[0] = Make_tree(a, 0, n - 1, root->c[1]);
83     Splay(root->c[1]->c[0], nil);
84 }
85 void Insert(int v)
86 {
87     Node *x = root, *y = nil;
88     while (x != nil)
89     {
90         y = x;
91         y->size++;
92         x = x->c[v >= x->key];
93     }
94     y->c[v >= y->key] = x = newNode(v, y);
95     Splay(x, nil);
96 }
97 void Remove(int l, int r)
98 {
99     Select(l, r);
100    //Recycle(root->c[1]->c[0]);
101    root->c[1]->c[0] = nil;
102    Splay(root->c[1], nil);
103 }
104 };

```

例题：旋转区间赋值求和求最大子序列。

注意打上懒标记后立即Pushup。Pushup(root->c[1]->c[0]),Pushup(root->c[1]),Pushup(root);

```

1 void Pushup(Node *x)
2 {
3     if (x == nil) return;
4     Pushdown(x); Pushdown(x->c[0]); Pushdown(x->c[1]);
5     x->size = x->c[0]->size+x->c[1]->size+1;
6
7     x->sum = x->c[0]->sum+x->c[1]->sum+x->key;
8     x->lsum = max(x->c[0]->lsum, x->c[0]->sum+x->key+max(0, x->c[1]->lsum));
9     x->rsum = max(x->c[1]->rsum, x->c[1]->sum+x->key+max(0, x->c[0]->rsum));
10    x->maxsum = max(max(x->c[0]->maxsum, x->c[1]->maxsum), x->key+max(0, x->c[0]->rsum)+max(0, x->c[1]->lsum));
11 }

```

```

12 void Pushdown(Node *x)
13 {
14     if (x == nil) return;
15     if (x->rev)
16     {
17         x->rev = 0;
18         x->c[0]->rev ^= 1;
19         x->c[1]->rev ^= 1;
20         swap(x->c[0], x->c[1]);
21
22         swap(x->lsum, x->rsum);
23     }
24     if (x->same)
25     {
26         x->same = false;
27         x->key = x->lazy;
28         x->sum = x->key*x->size;
29         x->lsum = x->rsum = x->maxsum = max(x->key, x->sum);
30         x->c[0]->same = true, x->c[0]->lazy = x->key;
31         x->c[1]->same = true, x->c[1]->lazy = x->key;
32     }
33 }
34
35 int main()
36 {
37     int totcas;
38     scanf("%d", &totcas);
39     for (int cas = 1; cas <= totcas; cas++)
40     {
41         Init();
42         sp.Init();
43         nil->lsum = nil->rsum = nil->maxsum = -Inf;
44         sp.Insert(0);
45         sp.Insert(0);
46
47         int n, m;
48         scanf("%d%d", &n, &m);
49         for (int i = 0; i < n; i++)
50             scanf("%d", &a[i]);
51         sp.Insert(0, a, n);
52
53         for (int i = 0; i < m; i++)
54         {
55             int pos, tot, c;
56             scanf("%s", buf);
57             if (strcmp(buf, "MAKE-SAME") == 0)
58             {
59                 scanf("%d%d%d", &pos, &tot, &c);
60                 sp.Select(pos-1, pos+tot-2);
61                 sp.root->c[1]->c[0]->same = true;
62                 sp.root->c[1]->c[0]->lazy = c;

```



```

63         sp.Pushup(sp.root->c[1]), sp.Pushup(sp.root);
64     }
65     else if (strcmp(buf,"INSERT") == 0)
66     {
67         scanf("%d%d",&pos,&tot);
68         for (int i = 0;i < tot;i++)
69             scanf("%d",&a[i]);
70         sp.Insert(pos,a,tot);
71     }
72     else if (strcmp(buf,"DELETE") == 0)
73     {
74         scanf("%d%d",&pos,&tot);
75         sp.Remove(pos-1,pos+tot-2);
76     }
77     else if (strcmp(buf,"REVERSE") == 0)
78     {
79         scanf("%d%d",&pos,&tot);
80         sp.Select(pos-1,pos+tot-2);
81         sp.root->c[1]->c[0]->rev ^= 1;
82         sp.Pushup(sp.root->c[1]), sp.Pushup(sp.root);
83     }
84     else if (strcmp(buf,"GET-SUM") == 0)
85     {
86         scanf("%d%d",&pos,&tot);
87         sp.Select(pos-1,pos+tot-2);
88         printf("%d\n",sp.root->c[1]->c[0]->sum);
89     }
90     else if (strcmp(buf,"MAX-SUM") == 0)
91     {
92         sp.Select(0,sp.root->size-3);
93         printf("%d\n",sp.root->c[1]->c[0]->maxsum);
94     }
95 }
96 }
97 return 0;
98 }

```

维护多个序列的时候，不需要建立很多Splay。只需要记录某个点在内存池中的绝对位置就可以了。

需要操作它所在的序列时直接Splay到nil。此时Splay的root所在的Splay就是这个序列了。新建序列的时候需要多加入两个额外节点。如果某个Splay只有两个节点了需要及时回收。

例题：Box（维护括号序列）

```

1  \\下面都是专用函数
2  \\判断x在不在f里面
3  bool Ancestor(Node *x,Node *f)
4  {
5      if (x == f) return true;
6      while (x->p != nil)
7      {
8          if (x->p == f) return true;

```

```

9         x = x->p;
10    }
11    return false;
12 }
13 \\把Splay v插入到pos后面, pos=nil时新开一个序列
14 void Insert(Node *pos, Node *v)
15 {
16     int pl;
17     if (pos == nil)
18     {
19         Init();
20         Insert(0), Insert(0);
21         pl = 0;
22     }
23     else
24     {
25         Splay(pos, nil);
26         pl = root->c[0]->size;
27     }
28     Select(pl, nil), Select(pl + 1, root);
29     root->c[1]->c[0] = v;
30     v->p = root->c[1];
31     Splay(v, nil);
32 }
33 \\把[l,r]转出来 (这里记录的是绝对位置)
34 void Select(Node *l, Node *r)
35 {
36     Splay(l, nil);
37     int pl = root->c[0]->size - 1;
38     Splay(r, nil);
39     int pr = root->c[0]->size - 1;
40     Select(pl, pr);
41 }
42 \\分离[l,r]
43 Node *Split(Node *l, Node *r)
44 {
45     Select(l, r);
46     Node *res = root->c[1]->c[0];
47     root->c[1]->c[0] = res->p = nil;
48     Splay(root->c[1], nil);
49     if (root->size == 2)
50     {
51         Recycle(root);
52         Init();
53     }
54     return res;
55 }
56
57 int main(int argc, char const *argv[])
58 {
59     freopen("P.in", "r", stdin);

```

```

60     bool first = true;
61     while (scanf("%d", &n) != EOF)
62     {
63         if (!first) puts("");
64         first = false;
65         Init();
66         for (int i = 0; i < n; i++)
67         {
68             \\建立独立的N个区间，记录绝对位置
69             sp.Init();
70             sp.Insert(0), sp.Insert(0);
71             sp.Insert(0,i+1),sp.Insert(1,i+1);
72             sp.Select(0, 0), l[i] = sp.root->c[1]->c[0];
73             sp.Select(1, 1), r[i] = sp.root->c[1]->c[0];
74         }
75         for (int i = 0; i < n; i++)
76         {
77             int f;
78             scanf("%d", &f);
79             if (f != 0)
80             {
81                 \\把[l[i],r[i]]插入到l[f-1]后面
82                 Node *pos = sp.Split(l[i], r[i]);
83                 sp.Insert(l[f - 1], pos);
84             }
85         }
86         scanf("%d", &n);
87         for (int i = 0; i < n; i++)
88         {
89             scanf("%s", com);
90             if (com[0] == 'Q')
91             {
92                 int pos;
93                 scanf("%d", &pos);
94                 \\求[l[pos-1],r[pos-1]]在哪个序列里面
95                 sp.Splay(l[pos - 1], nil);
96                 sp.Select(1, nil);
97                 printf("%d\\n", sp.root->key);
98             }
99             else
100             {
101                 int u, v;
102                 scanf("%d%d", &u, &v);
103                 if (v == 0)
104                     sp.Insert(nil, sp.Split(l[u-1], r[u-1]));
105                 else
106                 {
107                     sp.Select(l[u-1], r[u-1]);
108                     if (sp.Ancessor(l[v-1], sp.root->c[1]->c[0]) ==
                        false)

```

```

109         sp.Insert(l[v - 1], sp.Split(l[u-1], r[u
        -1]));
110     }
111 }
112 }
113 }
114 return 0;
115 }

```

5.2 动态树

懒标记是否及时Pushdown了?
修改之后有没有及时Pushup?

5.2.1 维护点权

查询链上的最长字段和
GetRoute是用换根写的

```

1  const int MaxN = 110000;
2
3  struct Node
4  {
5      int size, key;
6      bool rev;
7
8      // bool same;
9      // int lsum, rsum, sum, maxsum, sa;
10
11      Node *c[2];
12      Node *p;
13 } mem[MaxN], *cur, *nil, *pos[MaxN];
14
15 Node *newNode(int v, Node *p)
16 {
17     cur->c[0] = cur->c[1] = nil, cur->p = p;
18     cur->size = 1;
19     cur->key = v;
20     cur->rev = false;
21
22     // cur->same = false;
23     // cur->sa = 0;
24     // cur->lsum = cur->rsum = cur->maxsum = 0;
25     // cur->sum = v;
26
27     return cur++;
28 }
29
30 void Init()
31 {

```

```

32     cur = mem;
33     nil = newNode(0, cur);
34     nil->size = 0;
35 }
36
37 struct SplayTree
38 {
39     void Pushup(Node *x)
40     {
41         if (x == nil)    return;
42         Pushdown(x); Pushdown(x->c[0]); Pushdown(x->c[1]);
43         x->size = x->c[0]->size + x->c[1]->size + 1;
44
45         //      x->sum = x->c[0]->sum + x->c[1]->sum + x->key;
46         //      x->lsum = max(x->c[0]->lsum, x->c[0]->sum + x->key + max
47         //      (0, x->c[1]->lsum));
48         //      x->rsum = max(x->c[1]->rsum, x->c[1]->sum + x->key + max
49         //      (0, x->c[0]->rsum));
50         //      x->maxsum = max(max(x->c[0]->maxsum, x->c[1]->maxsum),
51         //      x->key + max(0, x->c[0]->rsum) + max(0, x->c[1]->lsum
52         //      ));
53     }
54     void Pushdown(Node *x)
55     {
56         if (x == nil)    return;
57         if (x->rev)
58         {
59             x->rev = 0;
60             x->c[0]->rev ^= 1;
61             x->c[1]->rev ^= 1;
62             swap(x->c[0], x->c[1]);
63         }
64         //注意修改与位置有关的量
65         //      swap(x->lsum, x->rsum);
66     }
67
68     //      if (x->same)
69     //      {
70     //          x->same = false;
71     //          x->key = x->sa;
72     //          x->sum = x->sa * x->size;
73     //          x->lsum = x->rsum = x->maxsum = max(0, x->sum);
74     //          if (x->c[0] != nil)
75     //              x->c[0]->same = true, x->c[0]->sa = x->sa;
76     //          if (x->c[1] != nil)
77     //              x->c[1]->same = true, x->c[1]->sa = x->sa;
78     //      }
79     }
80     bool isRoot(Node *x)
81     {
82         return (x == nil) || (x->p->c[0] != x && x->p->c[1] != x);
83     }
84 }

```

```

80     }
81     void Rotate(Node *x, int f)
82     {
83         if (isRoot(x))    return;
84         Node *y = x->p;
85         y->c[f ^ 1] = x->c[f], x->p = y->p;
86         if (x->c[f] != nil)
87             x->c[f]->p = y;
88         if (y != nil)
89         {
90             if (y == y->p->c[1])
91                 y->p->c[1] = x;
92             else if (y == y->p->c[0])
93                 y->p->c[0] = x;
94         }
95         x->c[f] = y, y->p = x;
96         Pushup(y);
97     }
98     void Splay(Node *x)
99     {
100         static Node *stack[MaxN];
101         int top = 0;
102         stack[top++] = x;
103         for (Node *y = x; !isRoot(y); y = y->p)
104             stack[top++] = y->p;
105         while (top)
106             Pushdown(stack[--top]);
107
108         while (!isRoot(x))
109         {
110             Node *y = x->p;
111             if (isRoot(y))
112                 Rotate(x, x == y->c[0]);
113             else
114             {
115                 int fd = y->p->c[0] == y;
116                 if (y->c[fd] == x)
117                     Rotate(x, fd ^ 1), Rotate(x, fd);
118                 else
119                     Rotate(y, fd), Rotate(x, fd);
120             }
121         }
122         Pushup(x);
123     }
124     Node *Access(Node *u)
125     {
126         Node *v = nil;
127         while (u != nil)
128         {
129             Splay(u);
130             v->p = u;

```

```

131         u->c[1] = v;
132         Pushup(u);
133         u = (v = u)->p;
134         if (u == nil)
135             return v;
136     }
137 }
138 Node *LCA(Node *u, Node *v)
139 {
140     Access(u);
141     return Access(v);
142 }
143 Node *Link(Node *u, Node *v)
144 {
145     Access(u);
146     Splay(u);
147     u->rev = true;
148     u->p = v;
149 }
150 void ChangeRoot(Node *u)
151 {
152     Access(u)->rev ^= 1;
153 }
154 Node *GetRoute(Node *u, Node *v)
155 {
156     ChangeRoot(u);
157     return Access(v);
158 }
159 };
160
161 int n, m;
162 SplayTree sp;
163
164 int main(int argc, char const *argv[])
165 {
166     while (scanf("%d", &n) != EOF)
167     {
168         Init();
169         for (int i = 0; i < n; i++)
170         {
171             int v;
172             scanf("%d", &v);
173             pos[i] = newNode(v, nil);
174         }
175         for (int i = 0; i < n - 1; i++)
176         {
177             int u, v;
178             scanf("%d%d", &u, &v);
179             u--, v--;
180             sp.Link(pos[u], pos[v]);
181         }

```

```

182
183 //      scanf("%d", &m);
184 //      for (int i = 0; i < m; i++)
185 //      {
186 //          int typ, u, v, c;
187 //          scanf("%d%d%d", &typ, &u, &v);
188 //          u--, v--;
189 //          if (typ == 1)
190 //              printf("%d\n", sp.GetRoute(pos[u], pos[v])->
maxsum);
191 //          else
192 //          {
193 //              scanf("%d", &c);
194 //              Node *p = sp.GetRoute(pos[u], pos[v]);
195 //              p->same = true;
196 //              p->sa = c;
197 //          }
198 //      }
199     }
200     return 0;
201 }

```

5.2.2 维护边权

刘汝佳的Happy Painting!
 查询链上边的不同颜色数量
 不能换根，但是可以Link和Cut

```

1  const int MaxN = 60000;
2
3  struct Node
4  {
5      int size, key;
6
7      int msk, lazy;
8
9      Node *c[2];
10     Node *p;
11 } mem[MaxN], *cur, *nil, *pos[MaxN];
12
13 Node *newNode(int v, Node *p)
14 {
15     cur->c[0] = cur->c[1] = nil, cur->p = p;
16     cur->size = 1;
17     cur->key = v;
18
19     cur->msk = 0;
20     cur->lazy = -1;
21
22     return cur++;
23 }

```



```

24
25 void Init()
26 {
27     cur = mem;
28     nil = newNode(0, cur);
29     nil->size = 0;
30 }
31
32 struct SplayTree
33 {
34     void Pushup(Node *x)
35     {
36         if (x == nil) return;
37         Pushdown(x);
38         Pushdown(x->c[0]);
39         Pushdown(x->c[1]);
40         x->size = x->c[0]->size + x->c[1]->size + 1;
41
42         x->msk = x->c[0]->msk | x->c[1]->msk | (1<<x->key);
43     }
44     void Pushdown(Node *x)
45     {
46         if (x == nil) return;
47
48         if (x->lazy != -1)
49         {
50             x->key = x->lazy;
51             x->msk = (1<<x->key);
52             x->c[0]->lazy = x->c[1]->lazy = x->lazy;
53             x->lazy = -1;
54         }
55     }
56     bool isRoot(Node *x)
57     {
58         return (x == nil) || (x->p->c[0] != x && x->p->c[1] != x);
59     }
60     void Rotate(Node *x, int f)
61     {
62         if (isRoot(x)) return;
63         Node *y = x->p;
64         y->c[f ^ 1] = x->c[f], x->p = y->p;
65         if (x->c[f] != nil)
66             x->c[f]->p = y;
67         if (y != nil)
68         {
69             if (y == y->p->c[1])
70                 y->p->c[1] = x;
71             else if (y == y->p->c[0])
72                 y->p->c[0] = x;
73         }
74         x->c[f] = y, y->p = x;

```

```

75     Pushup(y);
76 }
77 void Splay(Node *x)
78 {
79     static Node *stack[MaxN];
80     int top = 0;
81     stack[top++] = x;
82     for (Node *y = x; !isRoot(y); y = y->p)
83         stack[top++] = y->p;
84     while (top)
85         Pushdown(stack[--top]);
86
87     while (!isRoot(x))
88     {
89         Node *y = x->p;
90         if (isRoot(y))
91             Rotate(x, x == y->c[0]);
92         else
93         {
94             int fd = y->p->c[0] == y;
95             if (y->c[fd] == x)
96                 Rotate(x, fd ^ 1), Rotate(x, fd);
97             else
98                 Rotate(y, fd), Rotate(x, fd);
99         }
100     }
101     Pushup(x);
102 }
103 Node *Access(Node *u)
104 {
105     Node *v = nil;
106     while (u != nil)
107     {
108         Splay(u);
109         v->p = u;
110         u->c[1] = v;
111         Pushup(u);
112         u = (v = u)->p;
113         if (u == nil) return v;
114     }
115 }
116 Node *Root(Node *u)
117 {
118     Access(u);
119     Splay(u);
120     for (Pushdown(u); u->c[0] != nil; u = u->c[0])
121         Pushdown(u);
122     Splay(u);
123     return u;
124 }
125 Node *LCA(Node *u, Node *v)

```

```

126     {
127         if (Root(u) != Root(v))
128             return nil;
129         Access(u);
130         return Access(v);
131     }
132 void Cut(Node *u)
133 {
134     Access(u);
135     Splay(u);
136     u->c[0] = u->c[0]->p = nil;
137     Pushup(u);
138 }
139 void Link(Node *u, Node *v, int val)
140 {
141     Access(u);
142     Splay(u);
143     u->p = v;
144     u->key = val;
145     Pushup(u);
146 }
147 };
148
149 int cntbit(int x)
150 {
151     x = (x & 0x55555555) + ((x >> 1) & 0x55555555);
152     x = (x & 0x33333333) + ((x >> 2) & 0x33333333);
153     x = (x & 0x0F0F0F0F) + ((x >> 4) & 0x0F0F0F0F);
154     x = (x & 0x00FF00FF) + ((x >> 8) & 0x00FF00FF);
155     x = (x & 0x0000FFFF) + ((x >> 16) & 0x0000FFFF);
156     return x;
157 }
158
159 SplayTree sp;
160 int n,Q,f[MaxN];
161
162 int main(int argc, char const *argv[])
163 {
164     while (scanf("%d%d",&n,&Q) != EOF)
165     {
166         Init();
167         for (int i = 0; i < n; i++)
168         {
169             scanf("%d",&f[i]);
170             pos[i] = newNode(0, nil);
171         }
172         for (int i = 0; i < n; i++)
173         {
174             int col;
175             scanf("%d",&col);
176             if (f[i] > 0)

```

```

177         sp.Link(pos[i],pos[f[i]-1],col-1);
178     }
179     for (int q = 0; q < Q; q++)
180     {
181         int typ,x,y,c;
182         scanf("%d%d%d",&typ,&x,&y);
183         x--,y--;
184         if (typ == 3)
185         {
186             Node *lca = sp.LCA(pos[x],pos[y]);
187             if (lca == nil || x == y)
188             {
189                 printf("0_0\n");
190                 continue;
191             }
192             int totedge = lca->c[1]->size;
193             int msk = lca->c[1]->msk;
194
195             if (pos[x] != lca)
196             {
197                 sp.Splay(pos[x]);
198                 totedge += pos[x]->size;
199                 msk |= pos[x]->msk;
200             }
201
202             printf("%d_0%d\n",totedge,cntbit(msk));
203         }
204         else
205         {
206             scanf("%d",&c);
207             c--;
208             if (typ == 1)
209             {
210                 if (x == y) continue;
211
212                 Node *lca = sp.LCA(pos[x],pos[y]);
213                 if (pos[x] == lca) continue;
214
215                 sp.Cut(pos[x]);
216                 sp.Link(pos[x],pos[y],c);
217             }
218             else
219             {
220                 Node *lca = sp.LCA(pos[x],pos[y]);
221
222                 if (lca == nil || x == y)
223                     continue;
224
225                 lca->c[1]->lazy = c;
226                 sp.Pushup(lca->c[1]);
227             }

```

```

228         sp.Pushup(lca);
229         if (pos[x] != lca)
230         {
231             sp.Splay(pos[x]);
232             pos[x]->lazy = c;
233             sp.Pushup(pos[x]);
234         }
235     }
236 }
237 }
238 }
239 return 0;
240 }

```

5.3 可持久化线段树

区间第 k 小数，内存压缩版，POJ2014。

```

1  #include <cstdio>
2  #include <algorithm>
3  using namespace std;
4
5  const int MAXN=100000,MAXM=100000;
6
7  struct node
8  {
9      node *l,*r;
10     int sum;
11 }tree[MAXN*4+MAXM*20];
12
13 int N;
14 node *newnode()
15 {
16     tree[N].l=tree[N].r=NULL;
17     tree[N].sum=0;
18     return &tree[N++];
19 }
20 node *newnode(node *x)
21 {
22     tree[N].l=x->l;
23     tree[N].r=x->r;
24     tree[N].sum=x->sum;
25     return &tree[N++];
26 }
27 node *build(int l,int r)
28 {
29     node *x=newnode();
30     if (l<r)
31     {
32         int mid=l+r>>1;
33         x->l=build(l,mid);
34         x->r=build(mid+1,r);

```

```

35     x->sum=x->l->sum+x->r->sum;
36 }
37 else
38     x->sum=0;
39     return x;
40 }
41 node *update(node *x,int l,int r,int p,int v)
42 {
43     if (l<r)
44     {
45         int mid=l+r>>1;
46         node *nx=newnode(x);
47         if (p<=mid)
48         {
49             node *ret=update(x->l,l,mid,p,v);
50             nx->l=ret;
51         }
52         else
53         {
54             node *ret=update(x->r,mid+1,r,p,v);
55             nx->r=ret;
56         }
57         nx->sum=nx->l->sum+nx->r->sum;
58         return nx;
59     }
60     else
61     {
62         node *nx=newnode(x);
63         nx->sum+=v;
64         return nx;
65     }
66 }
67 int query(node *x1,node *x2,int l,int r,int k)
68 {
69     if (l<r)
70     {
71         int mid=l+r>>1;
72         int lsum=x2->l->sum-x1->l->sum;
73         if (lsum>=k)
74             return query(x1->l,x2->l,l,mid,k);
75         else
76             return query(x1->r,x2->r,mid+1,r,k-lsum);
77     }
78     else
79         return l;
80 }
81 char s[10];
82 node *root[MAXM+1];
83 int a[MAXN],b[MAXN];
84 int init(int n)
85 {

```

```

86     for (int i=0;i<n;i++)
87         b[i]=a[i];
88     sort(b,b+n);
89     int tn=unique(b,b+n)-b;
90     for (int i=0;i<n;i++)
91     {
92         int l=0,r=tn-1;
93         while (l<r)
94         {
95             int mid=l+r>>1;
96             if (b[mid]>=a[i])
97                 r=mid;
98             else
99                 l=mid+1;
100         }
101         a[i]=l;
102     }
103     return tn;
104 }
105 int main()
106 {
107     int cas=1,n;
108     while (scanf("%d",&n)!=EOF)
109     {
110         printf("Case_□%d:\n",cas++);
111         for (int i=0;i<n;i++)
112             scanf("%d",&a[i]);
113         int tn=init(n);
114         N=0;
115         root[0]=build(0,tn-1);
116         for (int i=1;i<=n;i++)
117             root[i]=update(root[i-1],0,tn-1,a[i-1],1);
118         int m;
119         scanf("%d",&m);
120         for (int i=0;i<m;i++)
121         {
122             int s,t;
123             scanf("%d%d",&s,&t);
124             printf("%d\n",b[query(root[s-1],root[t],0,tn-1,t-s
125                 +2>>1)]));
126         }
127     }
128     return 0;
129 }

```

5.4 treap正式版

支持翻转。

```

1 #include <cstdio>
2 #include <cstdlib>
3 #include <algorithm>

```

```
4 using namespace std;
5
6 const int MAXN = 100000;
7 const int MAXM = 100000;
8 const int inf = 0x7fffffff;
9 int a[MAXN];
10 struct Treap
11 {
12     int N;
13     Treap()
14     {
15         N = 0;
16         root = NULL;
17     }
18     void init()
19     {
20         N = 0;
21         root = NULL;
22     }
23     struct Treap_Node
24     {
25         Treap_Node *son[2]; //left & right
26         int value, fix;
27         bool lazy;
28         int size;
29         Treap_Node() {}
30         Treap_Node(int _value)
31         {
32             son[0] = son[1] = NULL;
33             value = _value;
34             fix = rand() * rand();
35             lazy = 0;
36             size = 1;
37         }
38         int sonSize(bool flag)
39         {
40             if (son[flag] == NULL)
41                 return 0;
42             else
43                 return son[flag]->size;
44         }
45     } node[MAXN], *root, *pos[MAXN];
46     void up(Treap_Node *p)
47     {
48         p->size = p->sonSize(0) + p->sonSize(1) + 1;
49     }
50     void down(Treap_Node *p)
51     {
52         if (!p->lazy)
53             return ;
54         for (int i = 0; i < 2; i++)
```



```

55         if (p->son[i])
56             p->son[i]->lazy = !p->son[i]->lazy;
57         swap(p->son[0], p->son[1]);
58         p->lazy = 0;
59     }
60     Treap_Node *merge(Treap_Node *p, Treap_Node *q)
61     {
62         if (p == NULL)
63             return q;
64         else if (q == NULL)
65             return p;
66         if (p->fix <= q->fix)
67         {
68             down(p);
69             p->son[1] = merge(p->son[1], q);
70             up(p);
71             return p;
72         }
73         else
74         {
75             down(q);
76             q->son[0] = merge(p, q->son[0]);
77             up(q);
78             return q;
79         }
80     }
81     pair<Treap_Node *, Treap_Node *> split(Treap_Node *p, int n)
82     {
83         if (p == NULL)
84             return make_pair((Treap_Node *)NULL, (Treap_Node *)NULL);
85         if (!n)
86             return make_pair((Treap_Node *)NULL, p);
87         if (n == p->size)
88             return make_pair(p, (Treap_Node *)NULL);
89         down(p);
90         if (p->sonSize(0) >= n)
91         {
92             pair<Treap_Node *, Treap_Node *> ret = split(p->son[0],
93                 n);
94             p->son[0] = ret.second;
95             up(p);
96             return make_pair(ret.first, p);
97         }
98         else
99         {
100             pair<Treap_Node *, Treap_Node *> ret = split(p->son[1],
101                 n - p->sonSize(0) - 1);
102             p->son[1] = ret.first;
103             up(p);
104             return make_pair(p, ret.second);

```

```

103     }
104 }
105 int smalls(Treap_Node *p,int value)
106 {
107     if (p==NULL)
108         return 0;
109     if (p->value<=value)
110         return 1+p->sonSize(0)+smalls(p->son[1],value);
111     else
112         return smalls(p->son[0],value);
113 }
114 void insert(int value)
115 {
116     Treap_Node *p = &node[N++];
117     *p = Treap_Node(value);
118     pair<Treap_Node *, Treap_Node *> ret = split(root, smalls(
119         root, value));
120     root = merge(merge(ret.first, p), ret.second);
121 }
122 void remove(int value)
123 {
124     pair<Treap_Node *, Treap_Node *> ret = split(root, smalls(
125         root, value) - 1);
126     root = merge(ret.first, split(ret.second, 1).second);
127 }
128 Treap_Node *build(int s, int t)
129 {
130     int idx = t + s >> 1;
131     Treap_Node *p = &node[N++];
132     *p = Treap_Node(a[idx]);
133     pos[a[idx]] = p;
134     if (idx > s)
135         p = merge(build(s, idx - 1), p);
136     if (idx < t)
137         p = merge(p, build(idx + 1, t));
138     up(p);
139     return p;
140 }
141 void build(int n)
142 {
143     root = build(0, n - 1);
144 }
145 void *reverse(int s, int t)
146 {
147     pair<Treap_Node *, Treap_Node *> tmp1, tmp2;
148     tmp1 = split(root, s - 1);
149     tmp2 = split(tmp1.second, t - s + 1);
150     tmp2.first->lazy = !tmp2.first->lazy;
151     root = merge(tmp1.first, merge(tmp2.first, tmp2.second));
152 }
153 };

```

```

152 Treap treap;
153 int main()
154 {
155     treap.init();
156     int n;
157     scanf("%d", &n);
158     for (int i = 0; i < n; i++)
159         scanf("%d", &a[i]);
160     treap.build(n);
161 }

```

5.5 树链剖分

5.5.1 点权

```

1  #include <cstdio>
2  #include <cstring>
3  #include <cstdlib>
4  #include <algorithm>
5  using namespace std;
6  const int MAX = 12000;
7  const int LOG = 15;
8  const int oo = 0x3f3f3f3f;
9  struct Edge
10 {
11     int to, w, id;
12     Edge* next;
13 } memo[MAX << 1], *cur, *g[MAX], *pree[MAX], *solid[MAX], *valid[
    MAX];
14 int dp[MAX][LOG], pos[MAX], lst[MAX], dep[MAX], cnt[MAX], h[MAX], K
    , n;
15 void init()
16 {
17     for (int i = 1; i <= n; i++)
18     {
19         g[i] = NULL;
20         valid[i] = NULL;
21         solid[i] = NULL;
22         pree[i] = NULL;
23     }
24     for (int i = 0; i < LOG; i++)
25     {
26         dp[1][i] = 1;
27     }
28     cur = memo;
29     K = 0;
30 }
31 void add(int u, int v, int w, int id)
32 {
33     cur->to = v;
34     cur->w = w;

```

```

35     cur->id = id;
36     cur->next = g[u];
37     g[u] = cur++;
38 }
39 void dfsLCA(int d, int u, int f)
40 {
41     dep[u] = d;
42     dp[u][0] = f;
43     cnt[u] = 1;
44     for (int i = 1; i < LOG; i++)
45     {
46         dp[u][i] = dp[dp[u][i - 1]][i - 1];
47     }
48     for (Edge* it = g[u]; it; it = it->next)
49     {
50         int v = it->to;
51         if (v != f)
52         {
53             pree[v] = it;
54             valid[it->id] = it;
55             dfsLCA(d + 1, v, u); //RE
56             cnt[u] += cnt[v];
57             if (solid[u] == NULL || cnt[solid[u]->to] < cnt[v])
58             {
59                 solid[u] = it;
60             }
61         }
62     }
63 }
64 void dfsChain(int u, int head)
65 {
66     h[u] = head;
67     if (solid[u])
68     {
69         lst[pos[u] = K++] = u;
70         dfsChain(solid[u]->to, head);
71     }
72     else
73     for (Edge* it = g[u]; it; it = it->next)
74     {
75         int v = it->to;
76         if (it != solid[u] && v != dp[u][0])
77         {
78             dfsChain(v, v);
79         }
80     }
81 }
82 int getLCA(int u, int v)
83 {
84     if (dep[u] < dep[v])
85         swap(u, v);

```

```

86     for (int st = 1 << (LOG - 1), i = LOG - 1; i >= 0; i--, st >>=
      1)
87     {
88         if (st <= dep[u] - dep[v])
89         {
90             u = dp[u][i];
91         }
92     }
93     if (u == v)
94         return u;
95     for (int i = LOG - 1; i >= 0; i--)
96     {
97         if (dp[u][i] != dp[v][i])
98         {
99             u = dp[u][i];
100            v = dp[v][i];
101        }
102    }
103    return dp[u][0];
104 }
105 struct Node
106 {
107     int l, r, ma, mi;
108     bool rev;
109 } seg[MAX << 2];
110 void reverse(int k)
111 {
112     seg[k].mi *= -1;
113     seg[k].ma *= -1;
114     seg[k].rev ^= 1;
115     swap(seg[k].mi, seg[k].ma);
116 }
117 void pushdown(int k)
118 {
119     if (seg[k].rev)
120     {
121         reverse(k << 1);
122         reverse(k << 1 | 1);
123         seg[k].rev = false;
124     }
125 }
126 void update(int k)
127 {
128     seg[k].mi = min(seg[k << 1].mi, seg[k << 1 | 1].mi);
129     seg[k].ma = max(seg[k << 1].ma, seg[k << 1 | 1].ma);
130 }
131 void init(int k, int l, int r)
132 {
133     seg[k].l = l;
134     seg[k].r = r;
135     seg[k].rev = false;

```

```

136     if (l == r)
137     {
138         seg[k].mi = seg[k].ma = solid[lst[l]]->w; //solid WA
139         return;
140     }
141     int mid = l + r >> 1;
142     init(k << 1, l, mid);
143     init(k << 1 | 1, mid + 1, r);
144     update(k);
145 }
146 void update(int k, int id, int v)
147 {
148     if (seg[k].l == seg[k].r)
149     {
150         seg[k].mi = seg[k].ma = solid[lst[id]]->w = v;
151         return;
152     }
153     pushdown(k);
154     int mid = seg[k].l + seg[k].r >> 1;
155     if (id <= mid)
156         update(k << 1, id, v);
157     else
158         update(k << 1 | 1, id, v);
159     update(k);
160 }
161 void reverse(int k, int l, int r)
162 {
163     if (seg[k].l > r || seg[k].r < l)
164         return;
165     if (seg[k].l >= l && seg[k].r <= r)
166     {
167         reverse(k);
168         return;
169     }
170     pushdown(k);
171     reverse(k << 1, l, r);
172     reverse(k << 1 | 1, l, r);
173     update(k);
174 }
175 int read(int k, int l, int r)
176 {
177     if (seg[k].l > r || seg[k].r < l)
178         return -oo;
179     if (seg[k].l >= l && seg[k].r <= r)
180         return seg[k].ma;
181     pushdown(k);
182     return max(read(k << 1, l, r), read(k << 1 | 1, l, r));
183 }
184 void setEdge(int id, int v)
185 {
186     Edge* it = valid[id];

```

```

187     if (h[it->to] != it->to)
188     {
189         update(1, pos[dp[it->to][0]], v);
190     }
191     else
192     {
193         it->w = v;
194     }
195 }
196 void negateLCA(int t, int u)
197 {
198     while (t != u)
199     {
200         int tmp = h[u];
201         if (dep[tmp] < dep[t])
202             tmp = t;
203         if (h[u] == u)
204         {
205             pree[u]->w *= -1;
206             u = dp[u][0];
207         }
208         else
209         {
210             reverse(1, pos[tmp], pos[dp[u][0]]);
211             u = tmp;
212         }
213     }
214 }
215 void negate(int u, int v)
216 {
217     int t = getLCA(u, v);
218     negateLCA(t, u);
219     negateLCA(t, v);
220 }
221 int maxLCA(int t, int u)
222 {
223     int ret = -oo;
224     while (t != u)
225     {
226         int tmp = h[u];
227         if (dep[tmp] < dep[t])
228             tmp = t;
229         if (h[u] == u)
230         {
231             ret = max(ret, pree[u]->w);
232             u = dp[u][0];
233         }
234         else
235         {
236             ret = max(ret, read(1, pos[tmp], pos[dp[u][0]]));
237             u = tmp;

```

```

238     }
239 }
240     return ret;
241 }
242 int query(int u, int v)
243 {
244     int t = getLCA(u, v);
245     return max(maxLCA(t, u), maxLCA(t, v));
246 }
247 int main()
248 {
249     int T;
250     int u, v, w;
251     char op[15];
252     scanf("%d", &T);
253     while (T--)
254     {
255         scanf("%d", &n);
256         init();
257         for (int i = 1; i < n; i++)
258         {
259             scanf("%d%d%d", &u, &v, &w);
260             add(u, v, w, i);
261             add(v, u, w, i);
262         }
263         dfsLCA(0, 1, 1);
264         dfsChain(1, 1);
265         init(1, 0, K - 1);
266         while (scanf("%s", op), op[0] != 'D')
267         {
268             scanf("%d%d", &u, &v);
269             if (op[0] == 'C')
270             {
271                 setEdge(u, v);
272             }
273             else if (op[0] == 'N')
274             {
275                 negate(u, v);
276             }
277             else
278             {
279                 printf("%d\n", query(u, v));
280             }
281         }
282     }
283     return 0;
284 }

```

5.5.2 边权

```

1 #include <cstdio>
2 #include <iostream>

```



```

3 #include <cstdlib>
4 #include <algorithm>
5 #include <cmath>
6 #include <cstring>
7 using namespace std;
8 int n,m,sum,pos;
9 int head[50005],e;
10 int s[50005],from[50005];
11 int fa[50005][20],deep[50005],num[50005];
12 int solid[50005],p[50005],fp[50005];
13 struct N
14 {
15     int l,r,mid;
16     int add,w;
17 }nod[50005*4];
18 struct M
19 {
20     int v,next;
21 }edge[100005];
22 void addedge(int u,int v)
23 {
24     edge[e].v=v;
25     edge[e].next=head[u];
26     head[u]=e++;
27
28     edge[e].v=u;
29     edge[e].next=head[v];
30     head[v]=e++;
31 }
32 void LCA(int st,int f,int d)
33 {
34     deep[st]=d;
35     fa[st][0]=f;
36     num[st]=1;
37     int i,v;
38     for(i=1;i<20;i++)
39         fa[st][i]=fa[fa[st][i-1]][i-1];
40     for(i=head[st];i!=-1;i=edge[i].next)
41     {
42         v=edge[i].v;
43         if(v!=f)
44         {
45             LCA(v,st,d+1);
46             num[st]+=num[v];
47             if(solid[st]==-1||num[v]>num[solid[st]])
48                 solid[st]=v;
49         }
50     }
51 }
52 void getpos(int st,int sp)
53 {

```

```

54     from[st]=sp;
55     if(solid[st]!=-1)
56     {
57         p[st]=pos++;
58         fp[p[st]]=st;
59         getpos(solid[st],sp);
60     }
61     else
62     {
63         p[st]=pos++;
64         fp[p[st]]=st;
65         return;
66     }
67     int i,v;
68     for(i=head[st];i!=-1;i=edge[i].next)
69     {
70         v=edge[i].v;
71         if(v!=solid[st]&&v!=fa[st][0])
72             getpos(v,v);
73     }
74 }
75 int getLCA(int u,int v)
76 {
77     if(deep[u]<deep[v])
78         swap(u,v);
79     int d=1<<19,i;
80     for(i=19;i>=0;i--)
81     {
82         if(d<=deep[u]-deep[v])
83             u=fa[u][i];
84         d>>=1;
85     }
86     if(u==v)
87         return u;
88     for(i=19;i>=0;i--)
89         if(fa[u][i]!=fa[v][i])
90         {
91             u=fa[u][i];
92             v=fa[v][i];
93         }
94     return fa[u][0];
95 }
96 void init(int p,int l,int r)
97 {
98     nod[p].l=l;
99     nod[p].r=r;
100     nod[p].mid=(l+r)>>1;
101     nod[p].add=0;
102     if(l==r)
103         nod[p].w=s[fp[l]];
104     else

```

```

105     {
106         init(p<<1,l,nod[p].mid);
107         init(p<<1|1,nod[p].mid+1,r);
108     }
109 }
110 void lazy(int p)
111 {
112     if(nod[p].add!=0)
113     {
114         nod[p<<1].add+=nod[p].add;
115         nod[p<<1|1].add+=nod[p].add;
116         nod[p].add=0;
117     }
118 }
119 void update(int p,int l,int r,int v)
120 {
121     if(nod[p].l==l&&nod[p].r==r)
122     {
123         nod[p].add+=v;
124         return;
125     }
126     lazy(p);
127     if(nod[p].mid<l)
128         update(p<<1|1,l,r,v);
129     else if(nod[p].mid>=r)
130         update(p<<1,l,r,v);
131     else
132     {
133         update(p<<1,l,nod[p].mid,v);
134         update(p<<1|1,nod[p].mid+1,r,v);
135     }
136 }
137 int read(int p,int l,int r)
138 {
139     if(nod[p].l==l&&nod[p].r==r)
140         return nod[p].w+nod[p].add;
141     lazy(p);
142     if(nod[p].mid<l)
143         return read(p<<1|1,l,r);
144     else if(nod[p].mid>=r)
145         return read(p<<1,l,r);
146 }
147 void jump(int st,int ed,int val)
148 {
149     while(deep[st]>=deep[ed])
150     {
151         int tmp=from[st];
152         if(deep[tmp]<deep[ed])
153             tmp=ed;
154         update(1,p[tmp],p[st],val);
155         st=fa[tmp][0];

```

```

156     }
157 }
158 void change(int st,int ed,int val)
159 {
160     int lca=getLCA(st,ed);
161     jump(st,lca,val);
162     jump(ed,lca,val);
163     jump(lca,lca,-val);
164 }
165 int main()
166 {
167     while(scanf("%d%d%d",&n,&m,&sum)==3)
168     {
169         int i;
170         s[0]=0;pos=0;deep[0]=-1;
171         memset(fa,0,sizeof(fa));
172         for(i=1;i<=n;i++)
173         {
174             solid[i]=-1;
175             scanf("%d",&s[i]);
176         }
177         memset(head,-1,sizeof(head));
178         e=0;
179         for(i=0;i<m;i++)
180         {
181             int a,b;
182             scanf("%d%d",&a,&b);
183             addedge(a,b);
184         }
185         LCA(1,0,0);
186         getpos(1,1);
187         init(1,0,pos-1);
188         for(i=0;i<sum;i++)
189         {
190             char que[5];
191             scanf("%s",que);
192             if(que[0]!='Q')
193             {
194                 int a,b,c;
195                 scanf("%d%d%d",&a,&b,&c);
196                 if(que[0]=='D')
197                     c=-c;
198                 change(a,b,c);
199             }
200             else
201             {
202                 int a;
203                 scanf("%d",&a);
204                 printf("%d\n",read(1,p[a],p[a]));
205             }
206         }

```

```

207     }
208     return 0;
209 }

```

5.6 划分树

```

1  int n,m;
2  struct elem
3  {
4      int v,index;
5  }a[120000];
6  int d[30][120000];
7  int s[30][120000];
8
9  bool cmp(elem a,elem b)
10 {
11     if (a.v == b.v)
12         return a.index <= b.index;
13     return a.v < b.v;
14 }
15
16 void build(int depth,int l,int r)
17 {
18     if (l == r)
19         return;
20     int mid = (l+r)/2;
21     int tl,tr;
22     tl = tr = 0;
23     for (int i = l;i <= r;i++)
24     {
25         if (cmp(a[d[depth][i]],a[mid]))
26         {
27             d[depth+1][l+tl] = d[depth][i];
28             tl++;
29         }
30         else
31         {
32             d[depth+1][mid+1+tr] = d[depth][i];
33             tr++;
34         }
35         s[depth][i] = tl;
36     }
37     build(depth+1,l,mid);
38     build(depth+1,mid+1,r);
39 }
40
41 int find(int depth,int dl,int dr,int fl,int fr,int k)
42 {
43     if (fl == fr)
44         return a[d[depth][fl]].v;
45     int ls,rs;
46     int mid = (dl+dr)/2;

```

```

47     ls = (fl == dl)? 0 : s[depth][fl-1];
48     rs = s[depth][fr];
49     return (rs-ls < k)? find(depth+1,mid+1,dr,mid+fl-dl-ls+1,mid+fr
        -dl-rs+1,k-(rs-ls)) : find(depth+1,dl,mid,dl+ls,dl+rs-1,k);
50 }
51
52 int main()
53 {
54     while (scanf("%d%d",&n,&m) != EOF)
55     {
56         for (int i = 1;i <= n;i++)
57         {
58             scanf("%d",&a[i].v);
59             a[i].index = i;
60         }
61         sort(a+1,a+n+1,cmp);
62         for (int i = 1;i <= n;i++)
63             d[0][a[i].index] = i;
64         build(0,1,n);
65         int l,r,k;
66         for (int i = 1;i <= m;i++)
67         {
68             scanf("%d%d%d",&l,&r,&k);
69             printf("%d\n",find(0,1,n,l,r,k));
70         }
71     }
72     return 0;
73 }

```

5.7 树状数组

```

1  int read(int k)
2  {
3      int sum = 0;
4      for (; k; k^=k&-k)
5          sum+=tree[k];
6      return sum;
7  }
8  void update(int k, int v)
9  {
10     for (; k<=MaxN; k+=k&-k)
11         tree[k]+=v;
12 }
13 int find_Kth(int k)
14 {
15     int idx = 0;
16     for(int i=20; i>=0; i--)
17     {
18         idx |= 1 << i;
19         if(idx <= MaxN && tree[idx] < k)
20             k -= tree[idx];
21         else idx ^= 1 << i;

```

```
22     }  
23     return idx + 1;  
24 }
```

6 图论

6.1 优先队列优化的dijkstra

```

1  #include<cstdio>
2  #include<cstring>
3  #include<iostream>
4  #include<algorithm>
5  #include<queue>
6  #include<vector>
7  using namespace std;
8  const int MAXN=100;
9  const int MAXM=1000;
10 int N,L;
11 int head[MAXN];
12 struct edges
13 {
14     int to,next,cost;
15 } edge[MAXM];
16 int dist[MAXN];
17 class states
18 {
19 public:
20     int cost,id;
21 };
22 class cmp
23 {
24 public:
25     bool operator()(const states &i,const states &j)
26     {
27         return i.cost>j.cost;
28     }
29 };
30 void init(int n)
31 {
32     N=n;
33     L=0;
34     for (int i=0; i<n; i++)
35         head[i]=-1;
36 }
37 void add_edge(int x,int y,int cost)
38 {
39     edge[L].to=y;
40     edge[L].cost=cost;
41     edge[L].next=head[x];
42     head[x]=L++;
43 }
44 int dijkstra(int s,int t)
45 {
46     memset(dist,63,sizeof(dist));
47     states u;

```



```

48     u.id=s;
49     u.cost=0;
50     dist[s]=0;
51     priority_queue<states,vector<states>,cmp> q;
52     q.push(u);
53     while (!q.empty())
54     {
55         u=q.top();
56         q.pop();
57         if (u.id==t) return dist[t];
58         if (u.cost!=dist[u.id]) continue;
59         for (int i=head[u.id]; i!=-1; i=edge[i].next)
60         {
61             states v=u;
62             v.id=edge[i].to;
63             if (dist[v.id]>dist[u.id]+edge[i].cost)
64             {
65                 v.cost=dist[v.id]=dist[u.id]+edge[i].cost;
66                 q.push(v);
67             }
68         }
69     }
70     return -1;
71 }
72 int main()
73 {
74     int n,m;
75     scanf("%d%d",&n,&m);
76     init(n);
77     for (int i=0; i<m; i++)
78     {
79         int x,y,z;
80         scanf("%d%d%d",&x,&y,&z);
81         add_edge(x,y,z);
82         add_edge(y,x,z);
83     }
84     int s,t;
85     scanf("%d%d",&s,&t);
86     printf("%d\n",dijkstra(s,t));
87     return 0;
88 }

```

6.2 SAP四版

```

1  const int MAXEDGE=20400;
2  const int MAXN=400;
3  const int inf=0x3fffffff;
4  struct edges
5  {
6      int cap,to,next,flow;
7  } edge[MAXEDGE+100];
8  struct nodes

```

```

9 {
10     int head,label,pre,cur;
11 } node[MAXN+100];
12 int L,N;
13 int gap[MAXN+100];
14 void init(int n)
15 {
16     L=0;
17     N=n;
18     for (int i=0; i<N; i++)
19         node[i].head=-1;
20 }
21 void add_edge(int x,int y,int z,int w)
22 {
23     edge[L].cap=z;
24     edge[L].flow=0;
25     edge[L].to=y;
26     edge[L].next=node[x].head;
27     node[x].head=L++;
28     edge[L].cap=w;
29     edge[L].flow=0;
30     edge[L].to=x;
31     edge[L].next=node[y].head;
32     node[y].head=L++;
33 }
34 int maxflow(int s,int t)
35 {
36     memset(gap,0,sizeof(gap));
37     gap[0]=N;
38     int u,ans=0;
39     for (int i=0; i<N; i++)
40     {
41         node[i].cur=node[i].head;
42         node[i].label=0;
43     }
44     u=s;
45     node[u].pre=-1;
46     while (node[s].label<N)
47     {
48         if (u==t)
49         {
50             int min=inf;
51             for (int i=node[u].pre; i!=-1; i=node[edge[i^1].to].pre)
52                 if (min>edge[i].cap-edge[i].flow)
53                     min=edge[i].cap-edge[i].flow;
54             for (int i=node[u].pre; i!=-1; i=node[edge[i^1].to].pre)
55             {
56                 edge[i].flow+=min;
57                 edge[i^1].flow-=min;

```

```

58         }
59         u=s;
60         ans+=min;
61         continue;
62     }
63     bool flag=false;
64     int v;
65     for (int i=node[u].cur; i!=-1; i=edge[i].next)
66     {
67         v=edge[i].to;
68         if (edge[i].cap-edge[i].flow && node[v].label+1==node[u]
69             ].label)
70         {
71             flag=true;
72             node[u].cur=node[v].pre=i;
73             break;
74         }
75     }
76     if (flag)
77     {
78         u=v;
79         continue;
80     }
81     node[u].cur=node[u].head;
82     int min=N;
83     for (int i=node[u].head; i!=-1; i=edge[i].next)
84         if (edge[i].cap-edge[i].flow && node[edge[i].to].label<
85             min)
86             min=node[edge[i].to].label;
87     gap[node[u].label]--;
88     if (!gap[node[u].label]) return ans;
89     node[u].label=min+1;
90     gap[node[u].label]++;
91     if (u!=s) u=edge[node[u].pre^1].to;
92 }

```

6.3 费用流三版

T了可以改成栈。

```

1  const int MAXM=60000;
2  const int MAXN=400;
3  const int inf=0x3fffffff;
4  int L,N;
5  int K;
6  struct edges
7  {
8      int to,next,cap,flow,cost;
9  } edge[MAXM];
10 struct nodes

```

```
11 {
12     int dis,pre,head;
13     bool visit;
14 } node[MAXN];
15 void init(int n)
16 {
17     N=n;
18     L=0;
19     for (int i=0; i<N; i++)
20         node[i].head=-1;
21 }
22 void add_edge(int x,int y,int cap,int cost)
23 {
24     edge[L].to=y;
25     edge[L].cap=cap;
26     edge[L].cost=cost;
27     edge[L].flow=0;
28     edge[L].next=node[x].head;
29     node[x].head=L++;
30     edge[L].to=x;
31     edge[L].cap=0;
32     edge[L].cost=-cost;
33     edge[L].flow=0;
34     edge[L].next=node[y].head;
35     node[y].head=L++;
36 }
37 bool spfa(int s,int t)
38 {
39     queue <int> q;
40     for (int i=0; i<N; i++)
41     {
42         node[i].dis=0x3fffffff;
43         node[i].pre=-1;
44         node[i].visit=0;
45     }
46     node[s].dis=0;
47     node[s].visit=1;
48     q.push(s);
49     while (!q.empty())
50     {
51         int u=q.front();
52         node[u].visit=0;
53         for (int i=node[u].head; i!=-1; i=edge[i].next)
54         {
55             int v=edge[i].to;
56             if (edge[i].cap>edge[i].flow &&
57                 node[v].dis>node[u].dis+edge[i].cost)
58             {
59                 node[v].dis=node[u].dis+edge[i].cost;
60                 node[v].pre=i;
61                 if (!node[v].visit)
```

```

62         {
63             node[v].visit=1;
64             q.push(v);
65         }
66     }
67 }
68     q.pop();
69 }
70 if (node[t].pre==-1)
71     return 0;
72 else
73     return 1;
74 }
75 int mcmf(int s,int t,int &cost)
76 {
77     int flow=0;
78     while (spfa(s,t))
79     {
80         int max=inf;
81         for (int i=node[t].pre; i!=-1; i=node[edge[i^1].to].pre)
82         {
83             if (max>edge[i].cap-edge[i].flow)
84                 max=edge[i].cap-edge[i].flow;
85         }
86         for (int i=node[t].pre; i!=-1; i=node[edge[i^1].to].pre)
87         {
88             edge[i].flow+=max;
89             edge[i^1].flow-=max;
90             cost+=edge[i].cost*max;
91         }
92         flow+=max;
93     }
94     return flow;
95 }

```

6.4 匈牙利

6.4.1 新版,隐式图可解

```

1 bool check(int u)
2 {
3     for (int i=head[u]; i!=-1; i=edge[i].next)
4     {
5         int v=edge[i].to;
6         if (matc[v]==u) continue;
7         if (!use[v])
8         {
9             use[v]=1;
10            if (matc[v]==-1 || check(matc[v]))
11            {
12                matc[v]=u;

```

```

13         matc[u]=v;
14         return 1;
15     }
16 }
17 }
18 return 0;
19 }
20 int match()
21 {
22     int ret=0;
23     memset(matc,-1,sizeof(matc));
24     for (int u=0; u<N; u++)
25     {
26         if (matc[u]!=-1) continue;
27         memset(use,0,sizeof(use));
28         if (check(u))
29             ret++;
30     }
31     return ret;
32 }

```

6.4.2 邻接矩阵

```

1 bool check(int u)
2 {
3     for (int v=0; v<N; v++)
4         if (am[u][v] && !use[v])
5         {
6             use[v]=1;
7             if (pre[v]==-1 || check(pre[v]))
8             {
9                 pre[v]=u;
10                return 1;
11            }
12        }
13    return 0;
14 }
15 int match()
16 {
17     int ret=0;
18     memset(pre,-1,sizeof(pre));
19     for (int u=0; u<N; u++)
20     {
21         memset(use,0,sizeof(use));
22         if (check(u))
23             ret++;
24     }
25     return ret;
26 }

```

6.4.3 邻接表

```

1 bool check(int u)

```

```

2 {
3     for (int i=head[u]; i!=-1; i=edge[i].next)
4     {
5         int v=edge[i].to;
6         if (!use[v])
7         {
8             use[v]=1;
9             if (pre[v]==-1 || check(pre[v]))
10            {
11                pre[v]=u;
12                return 1;
13            }
14        }
15    }
16    return 0;
17 }
18 int match()
19 {
20     int ret=0;
21     memset(pre,-1,sizeof(pre));
22     for (int u=1; u<=N; u++)
23     {
24         memset(use,0,sizeof(use));
25         if (check(u))
26             ret++;
27     }
28     return ret;
29 }

```

6.5 一般图匹配带花树

```

1 const int MaxN = 222;
2 int N;
3 bool Graph[MaxN+1][MaxN+1];
4 int Match[MaxN+1];
5 bool InQueue[MaxN+1], InPath[MaxN+1], InBlossom[MaxN+1];
6 int Head, Tail;
7 int Queue[MaxN+1];
8 int Start, Finish;
9 int NewBase;
10 int Father[MaxN+1], Base[MaxN+1];
11 int Count;
12 void CreateGraph()
13 {
14     int u, v;
15     memset(Graph, false, sizeof(Graph));
16     scanf("%d", &N);
17     while (scanf("%d%d", &u, &v) != EOF)
18         Graph[u][v] = Graph[v][u] = true;
19 }
20 void Push(int u)
21 {

```

```

22     Queue[Tail] = u;
23     Tail++;
24     InQueue[u] = true;
25 }
26 int Pop()
27 {
28     int res = Queue[Head];
29     Head++;
30     return res;
31 }
32 int FindCommonAncestor(int u,int v)
33 {
34     memset(InPath,false,sizeof(InPath));
35     while (true)
36     {
37         u = Base[u];
38         InPath[u] = true;
39         if (u == Start) break;
40         u = Father[Match[u]];
41     }
42     while (true)
43     {
44         v = Base[v];
45         if (InPath[v]) break;
46         v = Father[Match[v]];
47     }
48     return v;
49 }
50 void ResetTrace(int u)
51 {
52     int v;
53     while (Base[u] != NewBase)
54     {
55         v = Match[u];
56         InBlossom[Base[u]] = InBlossom[Base[v]] = true;
57         u = Father[v];
58         if (Base[u] != NewBase) Father[u] = v;
59     }
60 }
61 void BlossomContract(int u,int v)
62 {
63     NewBase = FindCommonAncestor(u,v);
64     memset(InBlossom,false,sizeof(InBlossom));
65     ResetTrace(u);
66     ResetTrace(v);
67     if (Base[u] != NewBase) Father[u] = v;
68     if (Base[v] != NewBase) Father[v] = u;
69     for (int tu = 1; tu <= N; tu++)
70         if (InBlossom[Base[tu]])
71         {
72             Base[tu] = NewBase;

```



```

73         if (!InQueue[tu]) Push(tu);
74     }
75 }
76 void FindAugmentingPath()
77 {
78     memset(InQueue,false,sizeof(InQueue));
79     memset(Father,0,sizeof(Father));
80     for (int i = 1; i <= N; i++)
81         Base[i] = i;
82     Head = Tail = 1;
83     Push(Start);
84     Finish = 0;
85     while (Head < Tail)
86     {
87         int u = Pop();
88         for (int v = 1; v <= N; v++)
89             if (Graph[u][v] && (Base[u] != Base[v]) && (Match[u] !=
90                 v))
91             {
92                 if ((v == Start) || ((Match[v] > 0) && (Father[
93                     Match[v]] > 0)))
94                     BlossomContract(u,v);
95                 else if (Father[v] == 0)
96                 {
97                     Father[v] = u;
98                     if (Match[v] > 0)
99                         Push(Match[v]);
100                     else
101                     {
102                         Finish = v;
103                         return;
104                     }
105                 }
106             }
107     }
108 }
109 void AugmentPath()
110 {
111     int u,v,w;
112     u = Finish;
113     while (u > 0)
114     {
115         v = Father[u];
116         w = Match[v];
117         Match[v] = u;
118         Match[u] = v;
119         u = w;
120     }
121 }
122 void Edmonds()
123 {

```

```

122     memset(Match,0,sizeof(Match));
123     for (int u = 1; u <= N; u++)
124         if (Match[u] == 0)
125         {
126             Start = u;
127             FindAugmentingPath();
128             if (Finish > 0) AugmentPath();
129         }
130 }
131 void PrintMatch()
132 {
133     for (int u = 1; u <= N; u++)
134         if (Match[u] > 0)
135             Count++;
136     printf("%d\n",Count);
137     for (int u = 1; u <= N; u++)
138         if (u < Match[u])
139             printf("%d□%d\n",u,Match[u]);
140 }
141 int main()
142 {
143     CreateGraph();
144     Edmonds();
145     PrintMatch();
146 }

```

6.6 KM

6.6.1 最大加权匹配

```

1  bool visx[N],visy[N]; //x,y中的点是否被访问
2  int lx[N],ly[N]; //x,y中的点的标号
3  int matchy[N]; //y中各点匹配状态
4  int map[N][N]; //二分图描述[x][y]
5  bool find(int x)
6  {
7      visx[x]=true;
8      int t;
9      for (int y=0;y<ycnt;y++)
10     {
11         if (!visy[y])
12         {
13             t=lx[x]+ly[y]-map[x][y];
14             if (t==0)
15             {
16                 visy[y]=true;
17                 if (matchy[y]==-1 || find(matchy[y]))
18                 {
19                     matchy[y]=x;
20                     return true;
21                 }
22             }

```

```

23     else if (lack>t) lack=t;
24     }
25 }
26 return false;
27 }
28 void KM()
29 {
30     memset(lx,0,sizeof(lx));
31     memset(ly,0,sizeof(ly));
32     memset(matchy,-1,sizeof(matchy));
33     for (int i=0;i<xcnt;i++)
34         for (int j=0;j<ycnt;j++)
35             if (map[i][j]>lx[i])
36                 lx[i]=map[i][j];
37     for (int x=0;x<xcnt;x++)
38     {
39         while (true)
40         {
41             memset(visx,false,sizeof(visx));
42             memset(visy,false,sizeof(visy));
43             lack=INFI;
44             if (find(x)) break;
45             for (int i=0;i<xcnt;i++)
46             {
47                 if (visx[i]) lx[i]-=lack;
48                 if (visy[i]) ly[i]+=lack;
49             }
50         }
51     }
52     int cost=0;
53     for (int i=0;i<ycnt;i++)
54         cost+=map[matchy[i]][i];
55 }

```

6.6.2 自认为正确的Kuhn_Munkras

未验证

```

1 #include<cstdio>
2 #include<cstring>
3 #include<algorithm>
4 using namespace std;
5 const int MAXN=100;
6 const int inf=0x3f3f3f3f;
7 bool visitx[MAXN],visity[MAXN];
8 int labx[MAXN],laby[MAXN],matx[MAXN],maty[MAXN],slack[MAXN];
9 int ma[MAXN][MAXN];
10 bool check(int x,int n)
11 {
12     visitx[x]=1;
13     for (int i=0; i<n; i++)
14         if (!visity[i])
15             if (labx[x]+laby[i]==ma[x][i])

```

```

16         {
17             visity[i]=1;
18             if (maty[i]==-1 || check(maty[i],n))
19             {
20                 matx[x]=i;
21                 maty[i]=x;
22                 return 1;
23             }
24         }
25         else
26             slack[i]=min(slack[i],labx[x]+laby[i]-ma[x][i]);
27
28     return 0;
29 }
30 void maintain(int n)
31 {
32     int diff=inf;
33     for (int i=0; i<n; i++)
34         if (!visity[i])
35             diff=min(diff,slack[i]);
36     for (int i=0; i<n; i++)
37     {
38         if (visitx[i])
39             labx[i]-=diff;
40         if (visity[i])
41             laby[i]+=diff;
42         else
43             slack[i]-=diff;
44     }
45 }
46 int Kuhn_Munkras(int n)
47 {
48     for (int i=0; i<n; i++)
49     {
50         labx[i]=-inf;
51         for (int j=0; j<n; j++)
52             labx[i]=max(labx[i],ma[i][j]);
53     }
54     memset(laby,0,4*n);
55     memset(matx,-1,4*n);
56     memset(maty,-1,4*n);
57     for (int i=0; i<n; i++)
58     {
59         memset(visitx,0,n);
60         memset(visity,0,n);
61         memset(slack,63,4*n);
62         while (!check(i,n))
63         {
64             maintain(n);
65             memset(visitx,0,n);
66             memset(visity,0,n);

```

```

67     }
68 }
69 int ret=0;
70 for (int i=0;i<n;i++)
71     ret+=labx[i]+laby[i];
72 return ret;
73 }
74 int main()
75 {
76     int n,m;
77     scanf("%d%d",&m,&n);
78     for (int i=m; i<n; i++)
79         for (int j=0; j<n; j++)
80             ma[i][j]=0;
81     for (int i=0; i<m; i++)
82         for (int j=0; j<n; j++)
83             scanf("%d",&ma[i][j]);
84     printf("%d\n",Kuhn_Munkras(n));
85     printf("%d",matx[0]+1);
86     for (int i=1;i<m;i++)
87         printf("□%d",matx[i]+1);
88     puts("");
89     return 0;
90 }

```

6.7 *二维平面图的最大流

待整理

```

1  #include <iostream>
2  #include <algorithm>
3  #include <cstdio>
4  #include <cstring>
5  #include <vector>
6  #include <cmath>
7  #include <map>
8  #include <queue>
9  using namespace std;
10
11 const int maxn = 100100;
12 const int inf = 0x3f3f3f3f;
13 struct Point
14 {
15     int x,y,id;
16     double theta;
17     Point() {}
18     Point(int _x,int _y)
19     {
20         x = _x;
21         y = _y;
22     }

```

```

23     Point(Point _s,Point _e,int _id)
24     {
25         id = _id;
26         x = _s.x-_e.x;
27         y = _s.y-_e.y;
28         theta = atan2(y,x);
29     }
30     bool operator < (const Point &b)const
31     {
32         return theta < b.theta;
33     }
34 };
35
36 map<pair<int,int>,int > idmap;
37 struct Edge
38 {
39     int from,to,next,cap,near,mark;
40 };
41 Edge edge[maxn*2];
42 int head[maxn],L;
43 int cntd[maxn];
44 void addedge(int u,int v,int cap)
45 {
46     cntd[u]++;
47     cntd[v]++;
48     idmap[make_pair(u,v)] = L;
49     edge[L].from = u;
50     edge[L].to = v;
51     edge[L].cap = cap;
52     edge[L].next = head[u];
53     edge[L].mark = -1;
54     head[u] = L++;
55 }
56
57 int rtp[maxn];
58 Point p[maxn],tp[maxn];
59 int n,m,S,T;
60 int vid;
61
62 struct Edge2
63 {
64     int to,next,dis;
65 } edge2[maxn*2];
66 int head2[maxn],L2;
67
68 void addedge2(int u,int v,int dis)
69 {
70     edge2[L2].to = v;
71     edge2[L2].dis = dis;
72     edge2[L2].next = head2[u];
73     head2[u] = L2++;

```

```

74 }
75
76 int dist[maxn];
77 bool inq[maxn];
78 int SPFA(int s,int t)
79 {
80     queue<int> Q;
81     memset(inq,false,sizeof(inq));
82     memset(dist,63,sizeof(dist));
83     Q.push(s);
84     dist[s] = 0;
85     while (!Q.empty())
86     {
87         int now = Q.front();
88         Q.pop();
89         for (int i = head2[now]; i != -1; i = edge2[i].next)
90             if (dist[edge2[i].to] > dist[now]+edge2[i].dis)
91             {
92                 dist[edge2[i].to] = dist[now]+edge2[i].dis;
93                 if (inq[edge2[i].to] == false)
94                 {
95                     inq[edge2[i].to] = true;
96                     Q.push(edge2[i].to);
97                 }
98             }
99         inq[now] = false;
100     }
101     return dist[t];
102 }
103
104 int main()
105 {
106     int totcas;
107     scanf("%d",&totcas);
108     for (int cas = 1; cas <= totcas; cas++)
109     {
110         idmap.clear();
111         L = 0;
112         scanf("%d%d",&n,&m);
113         S = T = 0;
114         for (int i = 0; i < n; i++)
115         {
116             head[i] = -1;
117             scanf("%d%d",&p[i].x,&p[i].y);
118             if (p[S].x > p[i].x)
119                 S = i;
120             if (p[T].x < p[i].x)
121                 T = i;
122             cntd[i] = 0;
123         }
124         //源汇中间加入一个特殊节点

```

```

125     head[n] = -1;
126     n ++;
127     addedge(S,n-1,inf);
128     addedge(n-1,S,inf);
129     addedge(T,n-1,inf);
130     addedge(n-1,T,inf);
131
132     for (int i = 0; i < m; i++)
133     {
134         int u,v,cap;
135         scanf("%d%d%d",&u,&v,&cap);
136         u--;
137         v--;
138         addedge(u,v,cap);
139         addedge(v,u,cap);
140     }
141
142     for (int i = 0; i < n; i++)
143     {
144         int tot = 0;
145         //源点汇点连到特殊点的方向需要特别考虑一下
146         if (i == S)
147             tp[tot++] = Point(Point(0,0),Point(-1,0),n-1);
148         else if (i == T)
149             tp[tot++] = Point(Point(0,0),Point(1,0),n-1);
150         else if (i == n-1)
151         {
152             tp[tot++] = Point(Point(0,0),Point(1,0),S);
153             tp[tot++] = Point(Point(0,0),Point(-1,0),T);
154         }
155         if (i < n-1)
156         {
157             for (int j = head[i]; j != -1; j = edge[j].next)
158             {
159                 if (i == S && edge[j].to == n-1) continue;
160                 if (i == T && edge[j].to == n-1) continue;
161                 tp[tot++] = Point(p[i],p[edge[j].to],edge[j].to);
162             }
163         }
164         sort(tp,tp+tot);
165         for (int j = 0; j < tot; j++)
166             rtp[tp[j].id] = j;
167         for (int j = head[i]; j != -1; j = edge[j].next)
168             edge[j].near = tp[(rtp[edge[j].to]+1)%tot].id;
169     }
170
171     vid = 0;
172     for (int i = 0; i < L; i++)
173         if (edge[i].mark == -1)
174         {

```



```

175         int now = edge[i].from;
176         int eid = i;
177         int to = edge[i].to;
178         while (true)
179         {
180             edge[eid].mark = vid;
181             eid ^= 1;
182             now = to;
183             to = edge[eid].near;
184             eid = idmap[make_pair(now,to)];
185
186             if (now == edge[i].from) break;
187         }
188         vid++;
189     }
190
191     L2 = 0;
192     for (int i = 0; i < vid; i++)
193         head2[i] = -1;
194     for (int i = 0; i < L; i++)
195         addedge2(edge[i].mark, edge[i^1].mark, edge[i].cap);
196     printf("%d\n", SPFA(edge[0].mark, edge[1].mark));
197 }
198 return 0;
199 }

```

6.8 强联通

```

1  int dfsnum[2000];
2  int low[2000];
3  int stack[2000];
4  int top;
5  int ans;
6  int an;
7  int be[2000];
8  int flag[2000];
9  void dfs(int x)
10 {
11     dfsnum[x] = low[x] = ans++;
12     stack[++top] = x;
13     flag[x] = 1;
14     for (int i = head[x]; i != -1; i = edge[i].next)
15     {
16         int y = edge[i].to;
17         if (dfsnum[y] == -1)
18         {
19             dfs(y);
20             low[x] = min(low[x], low[y]);
21         }
22         else if (flag[y] == 1)
23             low[x] = min(low[x], dfsnum[y]);

```

```

24     }
25     if (dfsnum[x] == low[x])
26     {
27         while (stack[top] != x)
28         {
29             flag[stack[top]] = 0;
30             be[stack[top]] = an;
31             top--;
32         }
33         flag[x] = 0;
34         be[x] = an++;
35         top--;
36     }
37 }

```

调用:

```

1 void SC()
2 {
3     memset(dfsnum, -1, sizeof(dfsnum));
4     memset(flag, 0, sizeof(flag));
5     top = 0;
6     an = 0;
7     ans = 0;
8     for (int i = 0; i < n; i++)
9         if (dfsnum[i] == -1)
10             dfs(i);
11 }

```

6.9 最大团以及相关知识

独立集: 独立集是指图的顶点集的一个子集,该子集的导出子图不含边.如果一个独立集不是任何一个独立集的子集,那么称这个独立集是一个极大独立集.一个图中包含顶点数目最多的独立集称为最大独立集。最大独立集一定是极大独立集,但是极大独立集不一定是最大的独立集。

支配集: 与独立集相对应的就是支配集,支配集也是图顶点集的一个子集,设 S 是图 G 的一个支配集,则对于图中的任意一个顶点 u ,要么属于集合 s ,要么与 s 中的顶点相邻。在 s 中除去任何元素后 s 不再是支配集,则支配集 s 是极小支配集。称 G 的所有支配集中顶点个数最少的支配集为最小支配集,最小支配集中的顶点个数成为支配数。

最小点的覆盖: 最小点的覆盖也是图的顶点集的一个子集,如果我们选中一个点,则称这个点将以他为端点的所有边都覆盖了。将图中所有的边都覆盖所用顶点数最少,这个集合就是最小的点的覆盖。

最大团: 图 G 的顶点的子集,设 D 是最大团,则 D 中任意两点相邻。若 u, v 是最大团,则 u, v 有边相连,其补图 u, v 没有边相连,所以图 G 的最大团=其补图的最大独立集。给定无向图 $G = (V, E)$,如果 U 属于 V ,并且对于任意 u, v 包含于 U 有 $\langle u, v \rangle$ 包含于 E ,则称 U 是 G 的完全子图, G 的完全子图 U 是 G 的团,当且仅当 U 不包含在 G 的更大的完全子图中, G 的最大团是指 G 中所含顶点数目最多的团。如果 U 属于 V ,并且对于任意 u, v 包含于 U 有 $\langle u, v \rangle$ 不包含于 E ,则称 U 是 G 的空子图, G 的空子图 U 是 G 的独立集,当且仅当 U 不包含在 G 的更大的独立集, G 的最大团是指 G 中所含顶点数目最多的独立集。

一些性质： 最大独立集+最小覆盖集= V ，最大团=补图的最大独立集，最小覆盖集=最大匹配

```

1  #include <cstdio>
2  bool am[100][100];
3  int ans;
4  int c[100];
5  int U[100][100];
6  int n;
7  bool dfs(int rest,int num)
8  {
9      if (!rest)
10     {
11         if (num>=ans)
12             return 1;
13         else
14             return 0;
15     }
16     int pre=-1;
17     for (int i=0;i<rest && rest-i+num>=ans;i++)
18     {
19         int idx=U[num][i];
20         if (num+c[idx]<ans)
21             return 0;
22         int nrest=0;
23         for (int j=i+1; j<rest; j++)
24             if (am[idx][U[num][j]])
25                 U[num+1][nrest++]=U[num][j];
26         if (dfs(nrest,num+1))
27             return 1;
28     }
29     return 0;
30 }
31 int main()
32 {
33     while (scanf("%d",&n),n)
34     {
35         for (int i=0;i<n;i++)
36             for (int j=0;j<n;j++)
37                 scanf("%d",&am[i][j]);
38         ans=0;
39         for (int i=n-1; i>=0; i--)
40         {
41             int rest=0;
42             for (int j=i+1; j<n; j++)
43                 if (am[i][j])
44                     U[0][rest++]=j;
45             ans+=dfs(rest,0);
46             c[i]=ans;
47         }
48         printf("%d\n",ans);

```

```

49     }
50     return 0;
51 }

```

6.10 双连通分量

标号从0起

```

1  #include<cstdio>
2  #include<cstring>
3  #include<stack>
4  #include<queue>
5  #include<algorithm>
6  using namespace std;
7  const int MAXN=100000*2;
8  const int MAXM=200000;
9  struct edges
10 {
11     int to,next;
12     bool cut,visit;
13 } edge[MAXN<<1];
14 int head[MAXN],low[MAXN],dpt[MAXN],L;
15 bool visit[MAXN],cut[MAXN];
16 void init(int n)
17 {
18     L=0;
19     memset(head,-1,4*n);
20     memset(visit,0,n);
21 }
22 void add_edge(int u,int v)
23 {
24     edge[L].cut=edge[L].visit=0;
25     edge[L].to=v;
26     edge[L].next=head[u];
27     head[u]=L++;
28 }
29 int idx;
30 stack<int> st;
31 int bcc[MAXM];
32 void dfs(int u,int fu,int deg)
33 {
34     cut[u]=0;
35     visit[u]=1;
36     low[u]=dpt[u]=deg;
37     int tot=0;
38     for (int i=head[u]; i!=-1; i=edge[i].next)
39     {
40         int v=edge[i].to;
41         if (edge[i].visit)
42             continue;
43         st.push(i/2);
44         edge[i].visit=edge[i^1].visit=1;

```

```

45     if (visit[v])
46     {
47         low[u]=dpt[v]>low[u]?low[u]:dpt[v];
48         continue;
49     }
50     dfs(v,u,deg+1);
51     edge[i].cut=edge[i^1].cut=(low[v]>dpt[u] || edge[i].cut);
52     if (u!=fu) cut[u]=low[v]>=dpt[u]?1:cut[u];
53     if (low[v]>=dpt[u] || u==fu)
54     {
55         while (st.top()!=i/2)
56         {
57             int x=st.top()*2,y=st.top()*2+1;
58             bcc[st.top()]=idx;
59             st.pop();
60         }
61         bcc[i/2]=idx++;
62         st.pop();
63     }
64     low[u]=low[v]>low[u]?low[u]:low[v];
65     tot++;
66 }
67 if (u==fu && tot>1) cut[u]=1;
68 }
69 int main()
70 {
71     int n,m;
72     while (scanf("%d%d",&n,&m)!=EOF)
73     {
74         init(n);
75         for (int i=0; i<m; i++)
76         {
77             int u,v;
78             scanf("%d%d",&u,&v);
79             add_edge(u,v);
80             add_edge(v,u);
81         }
82         idx=0;
83         for (int i=0; i<n; i++)
84             if (!visit[i])
85                 dfs(i,i,0);
86     }
87     return 0;
88 }

```

6.11 割点与桥

```

1 #include<cstdio>
2 #include<cstring>
3 const int MAXN=10000;
4 struct edges

```

```
5 {
6     int to,next;
7     bool cut,visit;
8     int from;
9 } edge[MAXN-1<<1];
10 int head[MAXN],low[MAXN],dfn[MAXN],L;
11 bool visit[MAXN],cut[MAXN];
12 void init(int n)
13 {
14     L=0;
15     memset(head,-1,4*n);
16     memset(cut,0,4*n);
17     memset(visit,0,4*n);
18 }
19 void add_edge(int u,int v)
20 {
21     edge[L].from=u;
22     edge[L].cut=edge[L].visit=0;
23     edge[L].to=v;
24     edge[L].next=head[u];
25     head[u]=L++;
26 }
27 int idx;
28 void dfs(int u,int fu)
29 {
30     visit[u]=1;
31     low[u]=dfn[u]=idx++;
32     int tot=0;
33     for (int i=head[u]; i!=-1; i=edge[i].next)
34     {
35         int v=edge[i].to;
36         if (edge[i].visit)
37             continue;
38         edge[i].visit=edge[i^1].visit=1;
39         if (visit[v])
40         {
41             low[u]=dfn[v]>low[u]?low[u]:dfn[v];
42             continue;
43         }
44         dfs(v,u);
45         edge[i].cut=edge[i^1].cut=low[v]>dfn[u] || edge[i].cut;
46         if (u!=fu) cut[u]=low[v]>=dfn[u]?1:cut[u];
47         low[u]=low[v]>low[u]?low[u]:low[v];
48         tot++;
49     }
50     if (u==fu && tot>1) cut[u]=1;
51 }
52 int main()
53 {
54     int t;
55     scanf("%d",&t);
```

```

56     while (t--)
57     {
58         int n,m;
59         scanf("%d%d",&n,&m);
60         init(n);
61         for (int i=0; i<m; i++)
62         {
63             int u,v;
64             scanf("%d%d",&u,&v);
65             add_edge(--u,--v);
66             add_edge(v,u);
67         }
68         for (int i=0; i<n; i++)
69             if (!visit[i])
70             {
71                 idx=0;
72                 dfs(i,i);
73             }
74     }
75     return 0;
76 }

```

6.12 LCA

在线LCA, bfs

```

1  #include<cstdio>
2  #include<cstring>
3  #include<queue>
4  using namespace std;
5  const int NSIZE = 50000;
6  const int DEG = 20;
7  struct trees
8  {
9
10     int fa[DEG];
11     int head,deg;
12 } tree[NSIZE];
13 struct edges
14 {
15     int to , next;
16 } edge[NSIZE];
17 struct states
18 {
19     int u,fu,deg;
20 };
21 int L;
22 void add_edge(int x, int y)
23 {
24     edge[L].to = y;
25     edge[L].next = tree[x].head;
26     tree[x].head = L++;
27 }

```

```

28 int Root;
29 void BFS(int s)
30 {
31     queue<states> que;
32     states st;
33     st.deg=0;
34     st.fu=st.u=s;
35     que.push(st);
36     while(!que.empty())
37     {
38         states st=que.front();
39         que.pop();
40         tree[st.u].deg = st.deg;
41         tree[st.u].fa[0] = st.fu;
42         for (int i=1;i<DEG;i++)
43             tree[st.u].fa[i]=s;
44         for (int tmp=st.fu,num=1;tree[tmp].deg;tmp=tree[st.u].fa[
            num++])
45             tree[st.u].fa[num]=tree[tmp].fa[num-1];
46         for(int i = tree[st.u].head ; i != -1; i = edge[i].next)
47         {
48             int v = edge[i].to;
49             if (v == st.fu) continue;
50             states nst;
51             nst.u=v;
52             nst.fu=st.u;
53             nst.deg=st.deg+1;
54             que.push(nst);
55         }
56     }
57 }
58 int LCA(int x, int y)
59 {
60     if(tree[x].deg > tree[y].deg) swap(x,y);
61     int hx=tree[x].deg,hy=tree[y].deg;
62     int tx=x,ty=y;
63     for (int det=hy-hx,i=0; det; det>>=1,i++)
64         if (det&1)
65             ty=tree[ty].fa[i];
66     if(tx == ty) return tx;
67     for (int i=DEG-1; i>=0; i--)
68     {
69         if(tree[tx].fa[i] == tree[ty].fa[i])
70             continue;
71         tx = tree[tx].fa[i];
72         ty = tree[ty].fa[i];
73     }
74     return tree[tx].fa[0];
75 }
76 int main()
77 {

```



```

78     int t;
79     scanf("%d",&t);
80     while(t--)
81     {
82         int n;
83         scanf("%d",&n);
84         L = 0;
85         for(int i = 0 ; i < n ; i++)
86             tree[i].head = -1;
87         for(int i = 0 ; i < n-1 ; i++)
88         {
89             int a,b;
90             scanf("%d%d",&a ,&b);
91             add_edge(a-1,b-1);
92             add_edge(b-1,a-1);
93         }
94         Root=0;
95         BFS(Root);
96         int a,b;
97         scanf("%d%d",&a,&b);
98         int lca=LCA(a-1,b-1)+1;
99         printf("%d\n",lca);
100     }
101     return 0;
102 }

```

6.13 最优比例生成树

```

1  #include<stdio.h>
2  #include<string.h>
3  #include<math.h>
4  struct
5  {
6      int x,y;
7      double z;
8  } node[1100];
9  struct
10 {
11     double l,c;
12 } map[1100][1100];
13 int n,l,f[1100],pre[1100];
14 double dis[1100];
15 double mst(double x)
16 {
17     int i,j,tmp;
18     double min,s=0,t=0;
19     memset(f,0,sizeof(f));
20     f[1]=1;
21     for (i=2; i<=n; i++)
22     {
23         dis[i]=map[1][i].c-map[1][i].l*x;

```

```

24     pre[i]=1;
25 }
26 for (i=1; i<n; i++)
27 {
28     min=1e10;
29     for (j=1; j<=n; j++)
30         if (!f[j] && min>dis[j])
31         {
32             min=dis[j];
33             tmp=j;
34         }
35     f[tmp]=1;
36     t+=map[pre[tmp]][tmp].l;
37     s+=map[pre[tmp]][tmp].c;
38     for (j=1; j<=n; j++)
39         if (!f[j] && map[tmp][j].c-map[tmp][j].l*x<dis[j])
40         {
41             dis[j]=map[tmp][j].c-map[tmp][j].l*x;
42             pre[j]=tmp;
43         }
44     }
45     return s/t;
46 }
47 int main()
48 {
49     int i,j;
50     double a,b;
51     scanf("%d",&n);
52     while (n)
53     {
54         for (i=1; i<=n; i++)
55             scanf("%d%d%lf",&node[i].x,&node[i].y,&node[i].z);
56         for (i=1; i<=n; i++)
57             for (j=i+1; j<=n; j++)
58             {
59                 map[j][i].l=map[i][j].l=sqrt(1.0*(node[i].x-node[j].x)*(node[i].x-node[j].x)+(node[i].y-node[j].y)*(node[i].y-node[j].y));
60                 map[j][i].c=map[i][j].c=fabs(node[i].z-node[j].z);
61             }
62         a=0,b=mst(a);
63         while (fabs(b-a)>1e-8)
64         {
65             a=b;
66             b=mst(a);
67         }
68         printf("%.3f\n",b);
69         scanf("%d",&n);
70     }
71 }

```

6.14 全局最小割

```

1  #include <iostream>
2  using namespace std;
3  const int maxn=510;
4  int map[maxn][maxn];
5  int n;
6  void contract(int x,int y)
7  {
8      int i,j;
9      for (i=0; i<n; i++)
10         if (i!=x) map[x][i]+=map[y][i],map[i][x]+=map[i][y];
11     for (i=y+1; i<n; i++) for (j=0; j<n; j++)
12     {
13         map[i-1][j]=map[i][j];
14         map[j][i-1]=map[j][i];
15     }
16     n--;
17 }
18 int w[maxn],c[maxn];
19 int sx,tx;
20 int mincut()
21 {
22     int i,j,k,t;
23     memset(c,0,sizeof(c));
24     c[0]=1;
25     for (i=0; i<n; i++) w[i]=map[0][i];
26     for (i=1; i+1<n; i++)
27     {
28         t=k=-1;
29         for (j=0; j<n; j++) if (c[j]==0&&w[j]>k)
30             k=w[t=j];
31         c[sx=t]=1;
32         for (j=0; j<n; j++) w[j]+=map[t][j];
33     }
34     for (i=0; i<n; i++) if (c[i]==0) return w[tx=i];
35 }
36 int main()
37 {
38     int i,j,k,m;
39     while (scanf("%d%d",&n,&m)!=EOF)
40     {
41         memset(map,0,sizeof(map));
42         while (m--)
43         {
44             scanf("%d%d%d",&i,&j,&k);
45             map[i][j]+=k;
46             map[j][i]+=k;
47         }
48         int mint=999999999;
49         while (n>1)

```

```

50     {
51         k=mincut();
52         if (k<mint) mint=k;
53         contract(sx,tx);
54     }
55     printf("%d\n",mint);
56 }
57 return 0;
58 }

```

6.15 欧拉路

6.15.1 有向图

```

1 void solve(int x)
2 {
3     int i;
4     if (!match[x])
5     {
6         path[++l]=x;
7         return ;
8     }
9     for (i=1; i<=n; i++)
10        if (b[x][i])
11        {
12            b[x][i]--;
13            match[x]--;
14            solve(i);
15        }
16    path[++l]=x;
17 }

```

6.15.2 无向图

```

1 void solve(int x)
2 {
3     int i;
4     if (!match[x])
5     {
6         path[++l]=x;
7         return ;
8     }
9     for (i=1; i<=n; i++)
10        if (b[x][i])
11        {
12            b[x][i]--;
13            b[i][x]--;
14            match[x]--;
15            match[i]--;
16            solve(i);
17        }
18    path[++l]=x;
19 }

```

6.15.3 混合图

zju1992

```

1 int in[MAXN+100],out[MAXN+100];
2 int main()
3 {
4     int t;
5     scanf("%d",&t);
6     while (t--)
7     {
8         int n,m;
9         scanf("%d%d",&n,&m);
10        N=n+2;L=-1;
11        for (int i=0;i<N;i++)
12            head[i]=-1;
13        memset(in,0,sizeof(in));
14        memset(out,0,sizeof(out));
15
16        for (int i=0;i<m;i++)
17        {
18            int x,y,z;
19            scanf("%d%d%d",&x,&y,&z);
20            in[y]++;out[x]++;
21            if (!z)
22                add_edge(x,y,1);
23        }
24        int flag=1;
25        for (int i=1;i<=n;i++)
26        {
27            if (in[i]-out[i]>0)
28                add_edge(i,n+1,(in[i]-out[i])/2);
29            else
30            if (out[i]-in[i]>0)
31                add_edge(0,i,(out[i]-in[i])/2);
32            //printf("%d %d %d\n",i,out[i],in[i]);
33            if ((in[i]+out[i])&1)
34            {
35                flag=0;
36                break;
37            }
38        }
39        maxflow(0,n+1);
40        for (int i=head[0];i!=-1;i=edge[i].next)
41            if (edge[i].cap>0 && edge[i].cap>edge[i].flow)
42            {
43                flag=0;
44                break;
45            }
46        if (flag)
47            puts("possible");
48        else

```

```

49         puts("impossible");
50     }
51     return 0;
52 }

```

6.16 K短路

```

1  #include<cstdio>
2  #include<cstring>
3  #include<queue>
4  using namespace std;
5  int K;
6  class states
7  {
8  public:
9      int cost,id;
10 };
11 int dist[1000];
12 class cmp
13 {
14 public:
15     bool operator()(const states &i,const states &j)
16     {
17         return i.cost>j.cost;
18     }
19 };
20 class cmp2
21 {
22 public:
23     bool operator()(const states &i,const states &j)
24     {
25         return i.cost+dist[i.id]>j.cost+dist[j.id];
26     }
27 };
28 struct edges
29 {
30     int to,next,cost;
31 } edger[100000],edge[100000];
32 int headr[1000],head[1000],Lr,L;
33 void dijkstra(int s)
34 {
35     states u;
36     u.id=s;
37     u.cost=0;
38     dist[s]=0;
39     priority_queue<states,vector<states>,cmp> q;
40     q.push(u);
41     while (!q.empty())
42     {
43         u=q.top();
44         q.pop();

```

```

45         if (u.cost!=dist[u.id]) continue;
46         for (int i=headr[u.id]; i!=-1; i=edger[i].next)
47         {
48             states v=u;
49             v.id=edger[i].to;
50             if (dist[v.id]>dist[u.id]+edger[i].cost)
51             {
52                 v.cost=dist[v.id]=dist[u.id]+edger[i].cost;
53                 q.push(v);
54             }
55         }
56     }
57 }
58 int num[1000];
59 void init(int n)
60 {
61     Lr=L=0;
62     memset(head,-1,4*n);
63     memset(headr,-1,4*n);
64     memset(dist,63,4*n);
65     memset(num,0,4*n);
66 }
67 void add_edge(int u,int v,int x)
68 {
69     edge[L].to=v;
70     edge[L].cost=x;
71     edge[L].next=head[u];
72     head[u]=L++;
73     edger[Lr].to=u;
74     edger[Lr].cost=x;
75     edger[Lr].next=headr[v];
76     headr[v]=Lr++;
77 }
78 int a_star(int s,int t)
79 {
80     if (dist[s]==0x3f3f3f3f)
81         return -1;
82     priority_queue<states,vector<states>,cmp2> q;
83     states tmp;
84     tmp.id=s;
85     tmp.cost=0;
86     q.push(tmp);
87     while (!q.empty())
88     {
89         states u=q.top();
90         q.pop();
91         num[u.id]++;
92         if (num[t]==K)
93             return u.cost;
94         for (int i=head[u.id]; i!=-1; i=edge[i].next)
95         {

```

```

96         int v=edge[i].to;
97         tmp.id=v;
98         tmp.cost=u.cost+edge[i].cost;
99         q.push(tmp);
100     }
101 }
102 return -1;
103 }
104 int main()
105 {
106     int n,m;
107     scanf("%d%d",&n,&m);
108     init(n);
109     for (int i=0; i<m; i++)
110     {
111         int u,v,x;
112         scanf("%d%d%d",&u,&v,&x);
113         add_edge(u-1,v-1,x);
114     }
115     int s,t;
116     scanf("%d%d%d",&s,&t,&K);
117     if (s==t)
118         K++;
119     dijkstra(t-1);
120     printf("%d\n",a_star(s-1,t-1));
121 }

```

6.17 稳定婚姻

假定有 n 个男生和 M 个女生，理想的拍拖状态就是对于每对情侣 (a,b) ，找不到另一对情侣 (c,d) 使得 c 更喜欢 b ， b 也更喜欢 c ，同理，对 a 来说也没有 (e,f) 使得 a 更喜欢 e 而 e 更喜欢 a ，当然最后会有一些人落单。这样子一个状态可以称为理想拍拖状态，它也有一个专业的名词叫稳定婚姻。

求解这个问题可以用一个专有的算法，延迟认可算法，其核心就是让每个男生按自己喜欢的顺序逐个向女生表白，例如leokan向一个女生求爱，这个过程中，若这个女生没有男朋友，那么这个女生就暂时成为leokan的女朋友，或这个女生喜欢她现有男朋友的程度没有喜欢leokan高，这个女生也暂时成为leokan的女朋友，而她原有的男朋友则再将就找下一个次喜欢的女生来当女朋友。

```

1 #include<string.h>
2 #include<stdio.h>
3 #define N 1050
4 int boy[N][N];
5 int girl[N][N];
6 int ans[N];
7 int cur[N];
8 int n;
9 void getMarry(int g)
10 {
11     for (int i=ans[g]+1;i<n;i++)
12     {
13         int b=girl[g][i]-1;
14         if (cur[b]<0)
15         {

```



```

16     ans[g]=i;
17     cur[b]=g;
18     return;
19 }
20 int og=cur[b];
21 if (boy[b][og] > boy[b][g])
22 {
23     cur[b]=g;
24     ans[g]=i;
25     getMarry(og);
26     return;
27 }
28 }
29 };
30 int main()
31 {
32     int t,a;
33     scanf("%d",&t);
34     while(t--)
35     {
36         memset(girl,0,sizeof(girl));
37         memset(boy,0,sizeof(boy));
38         scanf("%d",&n);
39         for (int i=0;i<n;i++)
40             for (int j=0;j<n;j++)
41                 scanf("%d",&girl[i][j]);
42         for (int i=0;i<n;i++)
43             for (int j=0;j<n;j++)
44             {
45                 scanf("%d",&a);
46                 boy[i][a-1]=j;
47             }
48         memset(cur,0xff,sizeof(cur));
49         memset(ans,0xff,sizeof(ans));
50         for (int i=0;i<n;i++)
51             getMarry(i);
52         for (int i=0;i<n;i++)
53             printf("%d\n",girl[i][ans[i]]);
54     }
55     return 0;
56 }

```

6.18 最小树形图

```

1 const int inf = 19921005;
2 int n,m,u,v,cost,dis[1001][1001],L;
3
4 void init(int n)
5 {
6     L = 0;
7     for (int i = 0; i < n; i++)

```

```

8         for (int j = 0; j < n; j++)
9             dis[i][j] = inf;
10    }
11
12    struct Edge
13    {
14        int u,v,cost;
15    };
16
17    Edge e[1001*1001];
18
19    int pre[1001],id[1001],visit[1001],in[1001];
20
21    int zhuliu(int root,int n,int m,Edge e[])
22    {
23        int res = 0,u,v;
24        while (true)
25        {
26            for (int i = 0; i < n; i++)
27                in[i] = inf;
28            for (int i = 0; i < m; i++)
29                if (e[i].u != e[i].v && e[i].cost < in[e[i].v])
30                {
31                    pre[e[i].v] = e[i].u;
32                    in[e[i].v] = e[i].cost;
33                }
34            for (int i = 0; i < n; i++)
35                if (i != root)
36                    if (in[i] == inf) return -1;
37            int tn = 0;
38            memset(id,-1,sizeof(id));
39            memset(visit,-1,sizeof(visit));
40            in[root] = 0;
41            for (int i = 0; i < n; i++)
42            {
43                res += in[i];
44                v = i;
45                while (visit[v] != i && id[v] == -1 && v != root)
46                {
47                    visit[v] = i;
48                    v = pre[v];
49                }
50                if(v != root && id[v] == -1)
51                {
52                    for(int u = pre[v] ; u != v ; u = pre[u])
53                        id[u] = tn;
54                    id[v] = tn++;
55                }
56            }
57            if(tn == 0) break;
58            for (int i = 0; i < n; i++)

```

```
59         if (id[i] == -1)
60             id[i] = tn++;
61     for (int i = 0; i < m;)
62     {
63         int v = e[i].v;
64         e[i].u = id[e[i].u];
65         e[i].v = id[e[i].v];
66         if (e[i].u != e[i].v)
67             e[i++].cost -= in[v];
68         else
69             swap(e[i], e[--m]);
70     }
71     n = tn;
72     root = id[root];
73 }
74 return res;
75 }
76
77 int main()
78 {
79     freopen("in.txt", "r", stdin);
80     while (scanf("%d%d", &n, &m) != EOF)
81     {
82         init(n);
83         for (int i = 0; i < m; i++)
84         {
85             scanf("%d%d%d", &u, &v, &cost);
86             if (u == v) continue;
87             dis[u][v] = min(dis[u][v], cost);
88         }
89         L = 0;
90         for (int i = 0; i < n; i++)
91             for (int j = 0; j < n; j++)
92                 if (dis[i][j] != inf)
93                 {
94                     e[L].u = i;
95                     e[L].v = j;
96                     e[L++].cost = dis[i][j];
97                 }
98         printf("%d\n", zhuliu(0, n, L, e));
99     }
100     return 0;
101 }
```

7 计算几何

7.1 基本函数

7.1.1 Point定义

```

1 struct Point
2 {
3     double x, y;
4     Point() {}
5     Point(double _x, double _y)
6     {
7         x = _x, y = _y;
8     }
9     Point operator -(const Point &b) const
10    {
11        return Point(x - b.x, y - b.y);
12    }
13    double operator *(const Point &b) const
14    {
15        return x * b.y - y * b.x;
16    }
17    double operator &(const Point &b) const
18    {
19        return x * b.x + y * b.y;
20    }
21    void transXY(double B)
22    {
23        double tx = x, ty = y;
24        x = tx*cos(B) - ty*sin(B);
25        y = tx*sin(B) + ty*cos(B);
26    }
27 };

```

7.1.2 Line定义

```

1 struct Line
2 {
3     Point s, e;
4     double k;
5     Line() {}
6     Line(Point _s, Point _e)
7     {
8         s = _s, e = _e;
9         k = atan2(e.y - s.y, e.x - s.x);
10    }
11    Point operator &(const Line &b) const
12    {
13        Point res = s;
14        //注意: 有些题目可能会有直线相交或者重合情况
15        //可以把返回值改成pair<Point,int>来返回两直线的状态。

```

```

16         double t = ((s - b.s) * (b.s - b.e)) / ((s - e) * (b.s - b.
           e));
17         res.x += (e.x - s.x) * t;
18         res.y += (e.y - s.y) * t;
19         return res;
20     }
21 };

```

7.1.3 距离：两点距离

```

1 double dist2(Point a, Point b)
2 {
3     return (a.x - b.x) * (a.x - b.x) + (a.y - b.y) * (a.y - b.y);
4 }

```

7.1.4 距离：点到直线距离

result: 点到直线最近点

```

1 Point NPT(Point P, Line L)
2 {
3     Point result;
4     double a, b, t;
5
6     a = L.p2.x - L.p1.x;
7     b = L.p2.y - L.p1.y;
8     t = ( (P.x - L.p1.x) * a + (P.y - L.p1.y) * b ) / (a * a + b *
        b);
9
10    result.x = L.p1.x + a * t;
11    result.y = L.p1.y + b * t;
12    return dist2(P, result);
13 }

```

7.1.5 距离：点到线段距离

res: 点到线段最近点

```

1 double dist2(Point p1, Point p2, Point p)
2 {
3     Point res;
4     double a, b, t;
5     a = p2.x - p1.x;
6     b = p2.y - p1.y;
7     t = ((p.x - p1.x) * a + (p.y - p1.y) * b) / (a * a + b * b);
8     if (t >= 0 && t <= 1)
9     {
10        res.x = p1.x + a * t;
11        res.y = p1.y + b * t;
12    }
13    else
14    {
15        if (dist2(p, p1) < dist2(p, p2))
16            res = p1;

```

```

17         else
18             res = p2;
19     }
20     return dist2(p, res);
21 }

```

旧版

```

1 double CalcDis(Point a, Point s, Point e) //点到线段距离
2 {
3     if (pmult(Point(s, e), Point(s, a)) < 0 || pmult(Point(e, s), Point(
4         e, a)) < 0)
5         return min(CalcDis(a, s), CalcDis(a, e));
6     return abs(xmult(Point(a, s), Point(a, e))) / CalcDis(s, e);
7 }

```

7.1.6 面积：多边形

点按逆时针排序。

```

1 double CalcArea(Point p[], int n)
2 {
3     double res = 0;
4     for (int i = 0; i < n; i++)
5         res += (p[i].x * p[(i + 1) % n].y) - (p[(i + 1) % n].x * p[i].y) / 2;
6     return res;
7 }

```

7.1.7 判断：线段相交

```

1 bool inter(Line l1, Line l2)
2 {
3     return (max(l1.s.x, l1.e.x) >= min(l2.s.x, l2.e.x) &&
4             max(l2.s.x, l2.e.x) >= min(l1.s.x, l1.e.x) &&
5             max(l1.s.y, l1.e.y) >= min(l2.s.y, l2.e.y) &&
6             max(l2.s.y, l2.e.y) >= min(l1.s.y, l1.e.y) &&
7             ((l2.s.x - l1.s.x) * (l1.e.y - l1.s.y)) * ((l2.e.x - l1.s.x) * (l1.e.y - l1.s.y)) <=
8                 0 &&
9             ((l1.s.x - l2.s.x) * (l2.e.y - l2.s.y)) * ((l1.e.x - l2.s.x) * (l2.e.y - l2.s.y)) <=
10                 0);
11 }

```

7.2 圆

7.2.1 面积：两圆相交

圆不可包含

```

1 double dis(int x, int y)
2 {
3     return sqrt((double)(x*x + y*y));
4 }
5 double area(int x1, int y1, int x2, int y2, double r1, double r2)
6 {

```

```

7   double s=dis(x2-x1,y2-y1);
8   if(r1+r2<s) return 0;
9   else if(r2-r1>s) return PI*r1*r1;
10  else if(r1-r2>s) return PI*r2*r2;
11  double q1=acos((r1*r1+s*s-r2*r2)/(2*r1*s));
12  double q2=acos((r2*r2+s*s-r1*r1)/(2*r2*s));
13  return (r1*r1*q1+r2*r2*q2-r1*s*sin(q1));
14 }

```

7.2.2 三角形外接圆

```

1 void CircumscribedCircle()
2 {
3     for (int i = 0; i < 3; i++)
4         scanf("%lf%lf",&p[i].x,&p[i].y);
5     tp = Point((p[0].x+p[1].x)/2,(p[0].y+p[1].y)/2);
6     l[0] = Line(tp,Point(tp.x-(p[1].y-p[0].y),tp.y+(p[1].x-p[0].x))
7         );
8     tp = Point((p[0].x+p[2].x)/2,(p[0].y+p[2].y)/2);
9     l[1] = Line(tp,Point(tp.x-(p[2].y-p[0].y),tp.y+(p[2].x-p[0].x))
10        );
11     tp = LineToLine(l[0],l[1]);
12     r = Point(tp,p[0]).Length();
13     printf("(%.6f,%.6f,%.6f)\n",tp.x,tp.y,r);
14 }

```

7.2.3 三角形内切圆

```

1 void InscribedCircle()
2 {
3     for (int i = 0; i < 3; i++)
4         scanf("%lf%lf",&p[i].x,&p[i].y);
5     if (xmult(Point(p[0],p[1]),Point(p[0],p[2])) < 0)
6         swap(p[1],p[2]);
7     for (int i = 0; i < 3; i++)
8         len[i] = Point(p[i],p[(i+1)%3]).Length();
9     tr = (len[0]+len[1]+len[2])/2;
10    r = sqrt((tr-len[0])*(tr-len[1])*(tr-len[2])/tr);
11    for (int i = 0; i < 2; i++)
12    {
13        v = Point(p[i],p[i+1]);
14        tv = Point(-v.y,v.x);
15        tr = tv.Length();
16        tv = Point(tv.x*r/tr,tv.y*r/tr);
17        tp = Point(p[i].x+tv.x,p[i].y+tv.y);
18        l[i].s = tp;
19        tp = Point(p[i+1].x+tv.x,p[i+1].y+tv.y);
20        l[i].e = tp;
21    }
22    tp = LineToLine(l[0],l[1]);
23    printf("(%.6f,%.6f,%.6f)\n",tp.x,tp.y,r);
24 }

```

7.2.4 点对圆的两个切点

```

1 void calc_qie(Point poi,Point o,double r,Point &result1,Point &
  result2) {
2     double line=sqrt((poi.x-o.x)*(poi.x-o.x)+(poi.y-o.y)*(poi.y-o.y
      ));
3     double angle=acos(r/line);
4     Point unitvector,lin;
5     lin.x=poi.x-o.x;
6     lin.y=poi.y-o.y;
7     unitvector.x=lin.x/sqrt(lin.x*lin.x+lin.y*lin.y)*r;
8     unitvector.y=lin.y/sqrt(lin.x*lin.x+lin.y*lin.y)*r;
9     result1=Rotate(unitvector,-angle);
10    result2=Rotate(unitvector,angle);
11    result1.x+=o.x;
12    result1.y+=o.y;
13    result2.x+=o.x;
14    result2.y+=o.y;
15    return;
16 }

```

7.2.5 两圆公切点

```

1 void Gao()
2 {
3     tn = 0;
4     Point a,b,vab;
5     double tab,tt,dis,theta;
6     for (int i = 0; i < tc; i++)
7         for (int j = 0; j < tc; j++)
8             if (i != j)
9                 {
10                     a = c[i];
11                     b = c[j];
12                     vab = Point(a,b);
13                     tab = atan2(vab.y,vab.x);
14                     dis = sqrt(vab.x*vab.x+vab.y*vab.y);
15                     if (b.r > a.r)
16                         tt = asin((b.r-a.r)/dis);
17                     else
18                         tt = -asin((a.r-b.r)/dis);
19                     theta = tab+pi/2+tt;
20                     tp[tn++] = Point(a.x+a.r*cos(theta),a.y+a.r*sin(
      theta));
21                     tp[tn++] = Point(b.x+b.r*cos(theta),b.y+b.r*sin(
      theta));
22                 }
23 }

```


7.3 矩阵

7.3.1 基本矩阵

按向量 $\overrightarrow{(x,y,z)}$ 平移:

$$\begin{pmatrix} 1 & 0 & 0 & x \\ 0 & 1 & 0 & y \\ 0 & 0 & 1 & z \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

按比例 (x,y,z) 缩放:

$$\begin{pmatrix} x & 0 & 0 & 0 \\ 0 & y & 0 & 0 \\ 0 & 0 & z & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

绕向量 $\overrightarrow{(x,y,z)}$ 旋转 $angle$ 角度:

$$\begin{pmatrix} x^2 \times (1-c) + c & x \times y \times (1-c) - z \times s & x \times z \times (1-c) + y \times s & 0 \\ y \times x \times (1-c) + z \times s & y^2 \times (1-c) + c & y \times z \times (1-c) - x \times s & 0 \\ x \times z \times (1-c) - y \times s & y \times z \times (1-c) + x \times s & z^2 \times (1-c) + c & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{cases} s = \sin(angle) \\ c = \cos(angle) \end{cases}$$

7.3.2 刘汝佳的几何教室

```

1  const double pi = acos(-1.0);
2
3  int n,m,q;
4  struct Point
5  {
6      double a,b,c,d;
7  };
8  Point p[50000],f[50000];
9
10 double a,b,c,theta,mt[4][4],tmp[4][4],tmt[4][4],rmt[4][8];
11 char com[20];
12
13 void TRANSLATE()
14 {
15     memset(tmt,0,sizeof(tmt));
16     tmt[0][0] = tmt[1][1] = tmt[2][2] = tmt[3][3] = 1;
17     tmt[3][0] = a;
18     tmt[3][1] = b;
19     tmt[3][2] = c;
20     memset(tmp,0,sizeof(tmp));
21     for (int i = 0; i < 4; i++)
22         for (int j = 0; j < 4; j++)
23             for (int k = 0; k < 4; k++)
24                 tmp[i][j] += mt[i][k]*tmt[k][j];
25     for (int i = 0; i < 4; i++)
26         for (int j = 0; j < 4; j++)

```

```

27         mt[i][j] = tmp[i][j];
28     }
29
30 void ROTATE()
31 {
32     theta = -theta*pi/180;
33     memset(tmt,0,sizeof(tmt));
34     tmt[3][3] = 1;
35     tmt[0][0] = cos(theta)+(1-cos(theta))*a*a;
36     tmt[1][0] = (1-cos(theta))*a*b+c*sin(theta);
37     tmt[2][0] = (1-cos(theta))*a*c-b*sin(theta);
38     tmt[0][1] = (1-cos(theta))*a*b-c*sin(theta);
39     tmt[1][1] = cos(theta)+(1-cos(theta))*b*b;
40     tmt[2][1] = (1-cos(theta))*b*c+a*sin(theta);
41     tmt[0][2] = (1-cos(theta))*a*c+b*sin(theta);
42     tmt[1][2] = (1-cos(theta))*b*c-a*sin(theta);
43     tmt[2][2] = cos(theta)+(1-cos(theta))*c*c;
44     memset(tmp,0,sizeof(tmp));
45     for (int i = 0; i < 4; i++)
46         for (int j = 0; j < 4; j++)
47             for (int k = 0; k < 4; k++)
48                 tmp[i][j] += mt[i][k]*tmt[k][j];
49     for (int i = 0; i < 4; i++)
50         for (int j = 0; j < 4; j++)
51             mt[i][j] = tmp[i][j];
52 }
53
54 void SCALE()
55 {
56     memset(tmt,0,sizeof(tmt));
57     tmt[0][0] = a;
58     tmt[1][1] = b;
59     tmt[2][2] = c;
60     tmt[3][3] = 1;
61     memset(tmp,0,sizeof(tmp));
62     for (int i = 0; i < 4; i++)
63         for (int j = 0; j < 4; j++)
64             for (int k = 0; k < 4; k++)
65                 tmp[i][j] += mt[i][k]*tmt[k][j];
66     for (int i = 0; i < 4; i++)
67         for (int j = 0; j < 4; j++)
68             mt[i][j] = tmp[i][j];
69 }
70
71 void solvep(Point p)
72 {
73     memset(tmt,0,sizeof(tmt));
74     tmt[0][0] = p.a;
75     tmt[0][1] = p.b;
76     tmt[0][2] = p.c;
77     tmt[0][3] = 1;

```

```

78     memset(tmp,0,sizeof(tmp));
79     for (int i = 0; i < 1; i++)
80         for (int j = 0; j < 4; j++)
81             for (int k = 0; k < 4; k++)
82                 tmp[i][j] += tmt[i][k]*mt[k][j];
83     printf("%.2f_%.2f_%.2f\n",tmp[0][0],tmp[0][1],tmp[0][2]);
84 }
85
86 void solvef(Point f)
87 {
88     memset(tmt,0,sizeof(tmt));
89     tmt[0][0] = f.a;
90     tmt[1][0] = f.b;
91     tmt[2][0] = f.c;
92     tmt[3][0] = 0;
93     memset(tmp,0,sizeof(tmp));
94     for (int i = 0;i < 4;i++)
95         for (int j = 0;j < 1;j++)
96             for (int k = 0;k < 4;k++)
97                 tmp[i][j] += mt[i][k]*tmt[k][j];
98     tmp[3][0] += f.d;
99     double kk = tmp[0][0]*tmp[0][0]+tmp[1][0]*tmp[1][0]+tmp[2][0]*
    tmp[2][0];
100     kk = sqrt(1/kk);
101     for (int i = 0;i < 4;i++)
102         printf("%.2f_",tmp[i][0]*kk);
103     printf("\n");
104 }
105
106 void solvermt()
107 {
108     memset(rmt,0,sizeof(rmt));
109     for (int i = 0;i < 4;i++)
110         for (int j = 0;j < 4;j++)
111             rmt[i][j] = mt[i][j];
112     rmt[0][4] = rmt[1][5] = rmt[2][6] = rmt[3][7] = 1;
113     for (int i = 0;i < 4;i++)
114     {
115         for (int j = i;j < 4;j++)
116             if (fabs(rmt[j][i]) > 1e-8)
117             {
118                 for (int k = i;k < 8;k++)
119                     swap(rmt[i][k],rmt[j][k]);
120                 break;
121             }
122         double tt = rmt[i][i];
123         for (int j = i;j < 8;j++)
124             rmt[i][j] /= tt;
125         for (int j = 0;j < 4;j++)
126             if (i != j)
127 
```

```

128         tt = rmt[j][i];
129         for (int k = i; k < 8; k++)
130             rmt[j][k] -= rmt[i][k]*tt;
131     }
132 }
133 for (int i = 0; i < 4; i++)
134     for (int j = 0; j < 4; j++)
135         mt[i][j] = rmt[i][4+j];
136 }
137
138 int main()
139 {
140     scanf("%d%d%d", &n, &m, &q);
141     for (int i = 0; i < n; i++)
142         scanf("%lf%lf%lf", &p[i].a, &p[i].b, &p[i].c);
143     for (int i = 0; i < m; i++)
144         scanf("%lf%lf%lf%lf", &f[i].a, &f[i].b, &f[i].c, &f[i].d);
145     memset(mt, 0, sizeof(mt));
146     mt[0][0] = mt[1][1] = mt[2][2] = mt[3][3] = 1;
147     for (int i = 0; i < q; i++)
148     {
149         scanf("%s", com);
150         if (strcmp(com, "TRANSLATE") == 0)
151         {
152             scanf("%lf%lf%lf", &a, &b, &c);
153             TRANSLATE();
154         }
155         else if (strcmp(com, "ROTATE") == 0)
156         {
157             scanf("%lf%lf%lf%lf", &a, &b, &c, &theta);
158             ROTATE();
159         }
160         else if (strcmp(com, "SCALE") == 0)
161         {
162             scanf("%lf%lf%lf", &a, &b, &c);
163             SCALE();
164         }
165     }
166     //处理点
167     for (int i = 0; i < n; i++)
168         solvep(p[i]);
169     //处理面
170     solvermt();
171     for (int i = 0; i < m; i++)
172         solvef(f[i]);
173     return 0;
174 }

```

7.4 重心

```

1 Point CenterOfPolygon(Point poly[], int n)
2 {

```

```

3   Point p, p0, p1, p2, p3;
4   double m, m0;
5   p1 = poly[0];
6   p2 = poly[1];
7   p.x = p.y = m = 0;
8   for (int i = 2; i < n; i++)
9   {
10  p3 = poly[i];
11  p0.x = (p1.x + p2.x + p3.x) / 3.0;
12  p0.y = (p1.y + p2.y + p3.y) / 3.0;
13  m0 = p1.x * p2.y + p2.x * p3.y + p3.x * p1.y - p1.y * p2.x - p2.y
      * p3.x - p3.y * p1.x;
14  if (cmp(m + m0, 0.0) == 0)
15      m0 += eps;
16  p.x = (m * p.x + m0 * p0.x) / (m + m0);
17  p.y = (m * p.y + m0 * p0.y) / (m + m0);
18  m = m + m0;
19  p2 = p3;
20  }
21  return p;
22 }

```

7.5 KD树

查找某个点距离最近的点，基本思想是每次分治把点分成两部分，建议按照坐标规模决定是垂直划分还是水平划分，查找时先往分到的那一部分查找，然后根据当前最优答案决定是否去另一个区间查找。

```

1  bool Div[MaxN];
2  void BuildKD(int deep, int l, int r, Point p[])\\记得备份一下P
3  {
4      if (l > r) return;
5      int mid = l + r >> 1;
6      int minX, minY, maxX, maxY;
7      minX = min_element(p + l, p + r + 1, cmpX)->x;
8      minY = min_element(p + l, p + r + 1, cmpY)->y;
9      maxX = max_element(p + l, p + r + 1, cmpX)->x;
10     maxY = max_element(p + l, p + r + 1, cmpY)->y;
11     Div[mid] = (maxX - minX >= maxY - minY);
12     nth_element(p + l, p + mid, p + r + 1, Div[mid] ? cmpX : cmpY);
13     BuildKD(l, mid - 1, p);
14     BuildKD(mid + 1, r, p);
15 }
16
17 long long res;
18 void Find(int l, int r, Point a, Point p[])\\查找
19 {
20     if (l > r) return;
21     int mid = l + r >> 1;
22     long long dist = dist2(a, p[mid]);
23     if (dist > 0)//如果有重点不能这样判断
24         res = min(res, dist);
25     long long d = Div[mid] ? (a.x - p[mid].x) : (a.y - p[mid].y);

```

```

26     int l1, l2, r1, r2;
27     l1 = l, l2 = mid + 1;
28     r1 = mid - 1, r2 = r;
29     if (d > 0)
30         swap(l1, l2), swap(r1, r2);
31     Find(l1, r1, a, p);
32     if (d * d < res)
33         Find(l2, r2, a, p);
34 }

```

7.5.1 例题

查询一个点为中心的给定正方形内所有点并删除（2012金华网赛A）

```

1  #include <iostream>
2  #include <cstdio>
3  #include <cstring>
4  #include <algorithm>
5  #include <cmath>
6  #include <queue>
7  using namespace std;
8
9  const int MaxN = 100000;
10 struct Point
11 {
12     int x,y,r;
13     int id;
14     bool del;
15 };
16
17 int cmpTyp;
18 bool cmp(const Point& a,const Point& b)
19 {
20     if (cmpTyp == 0)
21         return a.x < b.x;
22     else
23         return a.y < b.y;
24 }
25
26 int cnt[MaxN];
27 bool Div[MaxN];
28 int minX[MaxN],minY[MaxN],maxX[MaxN],maxY[MaxN];
29 void BuildKD(int l,int r,Point p[])
30 {
31     if (l > r) return;
32     int mid = l+r>>1;
33     cmpTyp = 0;
34     minX[mid] = min_element(p+l,p+r+1,cmp)->x;
35     maxX[mid] = max_element(p+l,p+r+1,cmp)->x;
36     cmpTyp = 1;
37     minY[mid] = min_element(p+l,p+r+1,cmp)->y;

```

```

38     maxY[mid] = max_element(p+l,p+r+1,cmp)->y;
39
40     cnt[mid] = r-l+1;
41     cmpTyp = Div[mid] = (maxX[mid]-minX[mid] < maxY[mid]-minY[mid]);
42     nth_element(p+l,p+mid,p+r+1,cmp);
43     BuildKD(l,mid-1,p);
44     BuildKD(mid+1,r,p);
45 }
46
47 queue<int> Q;
48 int Find(int l,int r,Point a,Point p[])
49 {
50     if (l > r) return 0;
51     int mid = l+r>>1;
52     if (cnt[mid] == 0) return 0;
53
54     if (maxX[mid] < a.x-a.r ||
55         minX[mid] > a.x+a.r ||
56         maxY[mid] < a.y-a.r ||
57         minY[mid] > a.y+a.r)
58         return 0;
59
60     int totdel = 0;
61
62     if (p[mid].del == false)
63         if (abs(p[mid].x-a.x) <= a.r && abs(p[mid].y-a.y) <= a.r)
64             {
65                 p[mid].del = true;
66                 Q.push(p[mid].id);
67                 totdel++;
68             }
69
70     totdel += Find(l,mid-1,a,p);
71     totdel += Find(mid+1,r,a,p);
72
73     cnt[mid] -= totdel;
74
75     return totdel;
76 }
77
78 Point p[MaxN],tp[MaxN];
79 int n;
80
81 int main()
82 {
83     int cas = 1;
84     while (true)
85     {
86         scanf("%d",&n);
87         if (n == 0) break;
88

```

```

89     for (int i = 0; i < n; i++)
90     {
91         p[i].id = i;
92         int tx, ty;
93         scanf("%d%d%d", &tx, &ty, &p[i].r);
94         p[i].x = tx - ty;
95         p[i].y = tx + ty;
96         p[i].del = false;
97         tp[i] = p[i];
98     }
99     BuildKD(0, n - 1, tp);
100
101     printf("Case_#%d:\n", cas++);
102     int q;
103     scanf("%d", &q);
104     for (int i = 0; i < q; i++)
105     {
106         int id;
107         scanf("%d", &id);
108         int res = 0;
109         id--;
110         Q.push(id);
111         while (!Q.empty())
112         {
113             int now = Q.front();
114             Q.pop();
115             if (p[now].del == true) continue;
116             p[now].del = true;
117             res += Find(0, n - 1, p[now], tp);
118         }
119         printf("%d\n", res);
120     }
121 }
122 return 0;
123 }

```

7.6 半平面交

直线左边代表有效区域。

```

1 bool HPIcmp(Line a, Line b)
2 {
3     if (fabs(a.k - b.k) > eps) return a.k < b.k;
4     return ((a.s - b.s) * (b.e - b.s)) < 0;
5 }
6
7 Line Q[100];
8 void HPI(Line line[], int n, Point res[], int &resn)
9 {
10     int tot = n;
11     sort(line, line + n, HPIcmp);
12     tot = 1;

```



```

13     for (int i = 1; i < n; i++)
14         if (fabs(line[i].k - line[i - 1].k) > eps)
15             line[tot++] = line[i];
16     int head = 0, tail = 1;
17     Q[0] = line[0];
18     Q[1] = line[1];
19     resn = 0;
20     for (int i = 2; i < tot; i++)
21     {
22         if (fabs((Q[tail].e-Q[tail].s) * (Q[tail - 1].e-Q[tail -
23             1].s)) < eps ||
24             fabs((Q[head].e-Q[head].s) * (Q[head + 1].e-Q[head
25                 + 1].s)) < eps)
26             return;
27         while (head < tail && (((Q[tail]&Q[tail - 1]) - line[i].s)
28             * (line[i].e-line[i].s)) > eps)
29             tail--;
30         while (head < tail && (((Q[head]&Q[head + 1]) - line[i].s)
31             * (line[i].e-line[i].s)) > eps)
32             head++;
33         Q[++tail] = line[i];
34     }
35     while (head < tail && (((Q[tail]&Q[tail - 1]) - Q[head].s) * (Q
36         [head].e-Q[head].s)) > eps)
37         tail--;
38     while (head < tail && (((Q[head]&Q[head + 1]) - Q[tail].s) * (Q
39         [tail].e-Q[tail].s)) > eps)
40         head++;
41     if (tail <= head + 1) return;
42     for (int i = head; i < tail; i++)
43         res[resn++] = Q[i] & Q[i + 1];
44     if (head < tail + 1)
45         res[resn++] = Q[head] & Q[tail];
46 }

```

7.7 凸包

得到的凸包按照逆时针方向排序。

```

1 bool GScmp(Point a, Point b)
2 {
3     if (fabs(a.x - b.x) < eps)
4         return a.y < b.y - eps;
5     return a.x < b.x - eps;
6 }
7
8 void GS(Point p[], int n, Point res[], int &resn)
9 {
10     resn = 0;
11     int top = 0;
12     sort(p, p + n, GScmp);
13     for (int i = 0; i < n; i++)

```

```

14         if (resn < 2 || (res[resn - 1] - res[resn - 2]) * (p[i] -
15             res[resn - 1]) > eps)
16             res[resn++] = p[i++];
17         else
18             --resn;
19     top = resn - 1;
20     for (int i = n - 2; i >= 0;)
21         if (resn < top + 2 || (res[resn - 1] - res[resn - 2]) * (p[
22             i] - res[resn - 1]) > eps)
23             res[resn++] = p[i--];
24         else
25             --resn;
26     resn--;
27     if (resn < 3)    resn = 0;
28 }

```

7.8 直线与凸包求交点

复杂度 $O(\log n)$ 。

需要先预处理几个东西。

```

1 //二分[la,lb]这段区间那条边与line相交
2 int Gao(int la,int lb,Line line)
3 {
4     if (la > lb)
5         lb += n;
6     int l = la,r = lb,mid;
7     while (l < r)
8     {
9         mid = l+r+1>>1;
10        if (cmp((line.e-line.s)*(p[la]-line.s),0)*cmp((line.e-line.
11            s)*(p[mid]-line.s),0) >= 0)
12            l = mid;
13        else
14            r = mid-1;
15    }
16    return l%n;
17 }
18 //求l与凸包的交点
19 //先调用Gettheta预处理出凸包每条边的斜率，然后处理成升序排列
20 double theta[maxn];
21
22 void Gettheta()
23 {
24     for (int i = 0;i < n;i++)
25     {
26         Point v = p[(i+1)%n]-p[i];
27         theta[i] = atan2(v.y,v.x);
28     }
29     for (int i = 1;i < n;i++)

```

```

30         if (theta[i-1] > theta[i]+eps)
31             theta[i] += 2*pi;
32     }
33
34     double Calc(Line l)
35     {
36         double tnow;
37         Point v = l.e-l.s;
38         tnow = atan2(v.y,v.x);
39         if (cmp(tnow,theta[0]) < 0)         tnow += 2*pi;
40         int pl = lower_bound(theta,theta+n,tnow)-theta;
41         tnow = atan2(-v.y,-v.x);
42         if (cmp(tnow,theta[0]) < 0)         tnow += 2*pi;
43         int pr = lower_bound(theta,theta+n,tnow)-theta;
44         //pl和pr是在l方向上距离最远的点对
45         pl = pl%n;
46         pr = pr%n;
47
48         if (cmp(v*(p[pl]-l.s),0)*cmp(v*(p[pr]-l.s),0) >= 0)
49             return 0.0;
50
51         int xa = Gao(pl,pr,l);
52         int xb = Gao(pr,pl,l);
53
54         if (xa > xb)         swap(xa,xb);
55         //与[xa,xa+1]和[xb,xb+1]这两条线段相交
56
57         if (cmp(v*(p[xa+1]-p[xa]),0) == 0)         return 0.0;
58         if (cmp(v*(p[xb+1]-p[xb]),0) == 0)         return 0.0;
59
60         Point pa,pb;
61         pa = Line(p[xa],p[xa+1])&l;
62         pb = Line(p[xb],p[xb+1])&l;
63         //题目：求直线切凸包得到的两部分的面积
64         double area0 = sum[xb]-sum[xa+1]+(pa*p[xa+1])/2.0+(p[xb]*pb)
65             /2.0+(pb*pa)/2.0;
66         double area1 = sum[xa+n]-sum[xb+1]+(pb*p[xb+1])/2.0+(p[xa]*pa)
67             /2.0+(pa*pb)/2.0;
68
69         return min(area0,area1);
70     }
71 }

```

7.9 三维凸包

暴力写法

```

1 #define eps 1e-7
2 #define MAXV 505
3
4 struct pt
5 {

```

```

6     double x, y, z;
7     pt() {}
8     pt(double _x, double _y, double _z): x(_x), y(_y), z(_z) {}
9     pt operator - (const pt p1)
10    {
11        return pt(x - p1.x, y - p1.y, z - p1.z);
12    }
13    pt operator * (pt p)
14    {
15        return pt(y*p.z-z*p.y, z*p.x-x*p.z, x*p.y-y*p.x);
16    }
17    double operator ^ (pt p)
18    {
19        return x*p.x+y*p.y+z*p.z;
20    }
21 };
22 struct _3DCH
23 {
24     struct fac
25     {
26         int a, b, c;
27         bool ok;
28     };
29     int n;
30     pt P[MAXV];
31     int cnt;
32     fac F[MAXV*8];
33     int to[MAXV][MAXV];
34     double vlen(pt a)
35     {
36         return sqrt(a.x*a.x+a.y*a.y+a.z*a.z);
37     }
38     double area(pt a, pt b, pt c)
39     {
40         return vlen((b-a)*(c-a));
41     }
42     double volume(pt a, pt b, pt c, pt d)
43     {
44         return (b-a)*(c-a)^(d-a);
45     }
46     double ptof(pt &p, fac &f)
47     {
48         pt m = P[f.b]-P[f.a], n = P[f.c]-P[f.a], t = p-P[f.a];
49         return (m * n) ^ t;
50     }
51     void deal(int p, int a, int b)
52     {
53         int f = to[a][b];
54         fac add;
55         if (F[f].ok)
56         {

```

```

57         if (ptof(P[p], F[f]) > eps)
58             dfs(p, f);
59         else
60         {
61             add.a = b, add.b = a, add.c = p, add.ok = 1;
62             to[p][b] = to[a][p] = to[b][a] = cnt;
63             F[cnt++] = add;
64         }
65     }
66 }
67 void dfs(int p, int cur)
68 {
69     F[cur].ok = 0;
70     deal(p, F[cur].b, F[cur].a);
71     deal(p, F[cur].c, F[cur].b);
72     deal(p, F[cur].a, F[cur].c);
73 }
74 bool same(int s, int t)
75 {
76     pt &a = P[F[s].a], &b = P[F[s].b], &c = P[F[s].c];
77     return fabs(volume(a, b, c, P[F[t].a])) < eps && fabs(
78         volume(a, b, c,
79             P[F[t].b])) < eps && fabs(volume(a, b, c, P[F[t].c
80             ])) < eps;
81 }
82 void construct()
83 {
84     cnt = 0;
85     if (n < 4)
86         return;
87     bool sb = 1;
88     for (int i = 1; i < n; i++)
89     {
90         if (vlen(P[0] - P[i]) > eps)
91         {
92             swap(P[1], P[i]);
93             sb = 0;
94             break;
95         }
96     }
97     if (sb) return;
98     sb = 1;
99     for (int i = 2; i < n; i++)
100     {
101         if (vlen((P[0] - P[1]) * (P[1] - P[i])) > eps)
102         {
103             swap(P[2], P[i]);
104             sb = 0;
105             break;
106         }
107     }

```

```

106         if (sb)return;
107         sb = 1;
108         for (int i = 3; i < n; i++)
109         {
110             if (fabs((P[0] - P[1]) * (P[1] - P[2]) ^ (P[0] - P[i]))
111                 > eps)
112             {
113                 swap(P[3], P[i]);
114                 sb = 0;
115                 break;
116             }
117         }
118         if (sb)return;
119         fac add;
120         for (int i = 0; i < 4; i++)
121         {
122             add.a = (i+1)%4, add.b = (i+2)%4, add.c = (i+3)%4, add.
123                 ok = 1;
124             if (ptof(P[i], add) > 0)
125                 swap(add.b, add.c);
126             to[add.a][add.b] = to[add.b][add.c] = to[add.c][add.a]
127                 = cnt;
128             F[cnt++] = add;
129         }
130         for (int i = 4; i < n; i++)
131         {
132             for (int j = 0; j < cnt; j++)
133             {
134                 if (F[j].ok && ptof(P[i], F[j]) > eps)
135                 {
136                     dfs(i, j);
137                     break;
138                 }
139             }
140         }
141         int tmp = cnt;
142         cnt = 0;
143         for (int i = 0; i < tmp; i++)
144         {
145             if (F[i].ok)
146             {
147                 F[cnt++] = F[i];
148             }
149         }
150     }
151     //表面积
152     double area()
153     {
154         double ret = 0.0;
155         for (int i = 0; i < cnt; i++)
156         {

```

```

154         ret += area(P[F[i].a], P[F[i].b], P[F[i].c]);
155     }
156     return ret / 2.0;
157 }
158 //体积
159 double volume()
160 {
161     pt O(0, 0, 0);
162     double ret = 0.0;
163     for (int i = 0; i < cnt; i++)
164     {
165         ret += volume(O, P[F[i].a], P[F[i].b], P[F[i].c]);
166     }
167     return fabs(ret / 6.0);
168 }
169 //表面三角形数
170 int facetCnt_tri()
171 {
172     return cnt;
173 }
174 //表面多边形数
175 int facetCnt()
176 {
177     int ans = 0;
178     for (int i = 0; i < cnt; i++)
179     {
180         bool nb = 1;
181         for (int j = 0; j < i; j++)
182         {
183             if (same(i, j))
184             {
185                 nb = 0;
186                 break;
187             }
188         }
189         ans += nb;
190     }
191     return ans;
192 }
193
194 pt Fc[MAXV*8];
195 double V[MAXV*8];
196 pt Center()//重心
197 {
198     pt O(0,0,0);
199     for (int i = 0; i < cnt; i++)
200     {
201         Fc[i].x = (O.x+P[F[i].a].x+P[F[i].b].x+P[F[i].c].x)
202             /4.0;
203         Fc[i].y = (O.y+P[F[i].a].y+P[F[i].b].y+P[F[i].c].y)
204             /4.0;

```

```

203         Fc[i].z = (0.z+P[F[i].a].z+P[F[i].b].z+P[F[i].c].z)
                /4.0;
204         V[i] = volume(0,P[F[i].a],P[F[i].b],P[F[i].c]);
205     }
206     pt res = Fc[0],tmp;
207     double m = V[0];
208     for (int i = 1; i < cnt; i++)
209     {
210         if (fabs(m+V[i]) < eps)
211             V[i] += eps;
212         tmp.x = (m*res.x+V[i]*Fc[i].x)/(m+V[i]);
213         tmp.y = (m*res.y+V[i]*Fc[i].y)/(m+V[i]);
214         tmp.z = (m*res.z+V[i]*Fc[i].z)/(m+V[i]);
215         m += V[i];
216         res = tmp;
217     }
218     return res;
219 }
220 };
221
222 _3DCH hull;
223
224 int main()
225 {
226     while (scanf("%d",&hull.n) != EOF)
227     {
228         for (int i = 0; i < hull.n; i++)
229             scanf("%lf%lf%lf",&hull.P[i].x,&hull.P[i].y,&hull.P[i].
                z);
230         hull.construct();
231     }
232     return 0;
233 }

```

7.10 旋转卡壳

“对踵”

7.10.1 单个凸包

```

1 void solve(Point p[],int n)
2 {
3     Point v;
4     int cur = 1;
5     for (int i = 0;i < n;i++)
6     {
7         v = p[i]-p[(i+1)%n];
8         while (v*(p[(cur+1)%n]-p[cur]) < 0)
9             cur = (cur+1)%n;
10        //p[cur] -> p[i]

```



```

11         //p[cur] -> p[i+1]
12         //p[cur] -> (p[i],p[i+1])
13     }
14 }

```

7.10.2 两个凸包

注意初始点的选取，代码只是个示例。

有时候答案需要取 $\text{solve}(p_0, n, p_1, m)$ 和 $\text{solve}(p_1, m, p_0, n)$ 的最优值。

何老鱼说我是错的。。

```

1 void solve(Point p0[], int n, Point p1[], int m)
2 {
3     Point v;
4     int cur = 0;
5     for (int i = 0; i < n; i++)
6     {
7         v = p0[i] - p0[(i+1)%n];
8         while (v*(p1[(cur+1)%m] - p1[cur]) < 0)
9             cur = (cur+1)%m;
10        //p1[cur] -> p0[i]
11        //p1[cur] -> p0[i+1]
12        //p1[cur] -> (p0[i], p0[i+1])
13    }
14 }

```

7.10.3 外接矩形

```

1 void solve()
2 {
3     resa = resb = 1e100;
4     double dis1, dis2;
5     Point xp[4];
6     Line l[4];
7     int a, b, c, d;
8     int sa, sb, sc, sd;
9     a = b = c = d = 0;
10    sa = sb = sc = sd = 0;
11    Point va, vb, vc, vd;
12    for (a = 0; a < n; a++)
13    {
14        va = Point(p[a], p[(a+1)%n]);
15        vc = Point(-va.x, -va.y);
16        vb = Point(-va.y, va.x);
17        vd = Point(-vb.x, -vb.y);
18        if (sb < sa)
19        {
20            b = a;
21            sb = sa;
22        }
23        while (xmult(vb, Point(p[b], p[(b+1)%n])) < 0)

```

```

24     {
25         b = (b+1)%n;
26         sb++;
27     }
28     if (sc < sb)
29     {
30         c = b;
31         sc = sb;
32     }
33     while (xmult(vc,Point(p[c],p[(c+1)%n])) < 0)
34     {
35         c = (c+1)%n;
36         sc++;
37     }
38     if (sd < sc)
39     {
40         d = c;
41         sd = sc;
42     }
43     while (xmult(vd,Point(p[d],p[(d+1)%n])) < 0)
44     {
45         d = (d+1)%n;
46         sd++;
47     }
48
49     //卡在p[a],p[b],p[c],p[d]上
50     sa++;
51 }
52 }

```

7.11 三角形内点个数

7.11.1 无三点共线

```

1 Point p[1000], tp[2000], base;
2
3 bool cmp(const Point &a, const Point &b)
4 {
5     return a.theta < b.theta;
6 }
7
8 int cnt[1000][1000];
9 int cntleft[1000][1000];
10 int n, m;
11
12 int calc(int a, int b, int c)
13 {
14     Point p1 = p[b] - p[a], p2 = p[c] - p[a];
15     if (atan2(p1.y, p1.x) > atan2(p2.y, p2.x))
16         swap(b, c);
17     if ((p[b] - p[a]) * (p[c] - p[a]) > 0)
18         return cnt[a][c] - cnt[a][b] - 1;

```

```

19     else
20         return n - 3 - (cnt[a][c] - cnt[a][b] - 1);
21 }
22
23 int main(int argc, char const *argv[])
24 {
25     int totcas;
26     scanf("%d", &totcas);
27     for (int cas = 1; cas <= totcas; ++cas)
28     {
29         scanf("%d", &n);
30         for (int i = 0; i < n; ++i)
31         {
32             scanf("%lld%lld", &p[i].x, &p[i].y);
33             p[i].id = i;
34         }
35         for (int i = 0; i < n; ++i)
36         {
37             m = 0;
38             base = p[i];
39             for (int j = 0; j < n; ++j)
40                 if (i != j)
41                 {
42                     tp[m] = p[j];
43                     Point v = tp[m] - base;
44                     tp[m++].theta = atan2(v.y, v.x);
45                 }
46
47             sort(tp, tp + m, cmp);
48             for (int j = 0; j < m; ++j)
49                 tp[m + j] = tp[j];
50
51             //calc cnt
52             for (int j = 0; j < m; ++j)
53                 cnt[i][tp[j].id] = j;
54
55             //calc cntleft
56             for (int j = 0, k = 0, tot = 0; j < m; ++j)
57             {
58                 while (k == j || (k < j + m && (tp[j] - base) * (tp
59                     [k] - base) > 0))
60                     k++, tot++;
61                 cntleft[i][tp[j].id] = --tot;
62             }
63
64             printf("Case %d:\n", cas);
65             int q;
66             scanf("%d", &q);
67             for (int i = 0; i < q; ++i)
68             {

```

```

69         int x, y, z;
70         scanf("%d%d%d", &x, &y, &z);
71         if ((p[z] - p[x]) * (p[y] - p[x]) > 0)
72             swap(y, z);
73         int res = cntleft[x][z] + cntleft[z][y] + cntleft[y][x]
74             ];
75         res += calc(x, y, z) + calc(y, z, x) + calc(z, x, y);
76         res -= 2 * (n - 3);
77         printf("%d\n", res);
78     }
79     return 0;
80 }

```

7.11.2 有三点共线且点有类别之分

```

1  int n,n0,n1,m;
2  Point p[3000], tp[3000], base;
3
4  bool cmp(const Point &a, const Point &b)
5  {
6      if ((a-base)*(b-base) == 0)
7      {
8          return (a-base).getMol() < (b-base).getMol();
9      }
10     return a.theta < b.theta;
11 }
12
13 int cnt[100][100];
14 int cntleft[100][100];
15
16 int calc(int a,int b,int c)
17 {
18     Point p1 = p[b]-p[a],p2 = p[c]-p[a];
19     if (atan2(1.0*p1.y,1.0*p1.x) > atan2(1.0*p2.y,1.0*p2.x))
20         swap(b,c);
21     int res = cnt[a][c]-cnt[a][b];
22     if ((p[b]-p[a])*(p[c]-p[a]) > 0)
23         return res;
24     else
25         return n1-res;
26 }
27
28 int main()
29 {
30     int cas = 0;
31     while (scanf("%d%d",&n0,&n1) != EOF)
32     {
33         n = n1+n0;
34         for (int i = 0; i < n; i++)
35         {
36             scanf("%I64d%I64d",&p[i].x,&p[i].y);

```

```

37         p[i].id = i;
38     }
39     for (int i = 0; i < n0; ++i)
40     {
41         m = 0;
42         base = p[i];
43         for (int j = 0; j < n; ++j)
44             if (i != j)
45             {
46                 tp[m] = p[j];
47                 Point v = tp[m]-base;
48                 tp[m++].theta = atan2(1.0*v.y,1.0*v.x);
49             }
50
51         sort(tp, tp + m, cmp);
52         for (int j = 0; j < m; ++j)
53             tp[m + j] = tp[j];
54
55         for (int j = 0,tot = 0; j < m; ++j)
56         {
57             if (tp[j].id < n0)
58                 cnt[i][tp[j].id] = tot;
59             else
60                 tot++;
61         }
62
63         for (int j = 0, k = 0, tot = 0; j < m; ++j)
64         {
65             while (k == j || (k < j + m && (tp[j] - base) * (tp
66                 [k] - base) > 0))
67             {
68                 if (tp[k].id >= n0)
69                     tot++;
70                 k++;
71             }
72             if (tp[j].id >= n0)
73                 tot--;
74             else
75                 cntleft[i][tp[j].id] = tot;
76         }
77
78         int ans = 0;
79         for (int i = 0; i < n0; i++)
80             for (int j = i+1; j < n0; j++)
81                 for (int k = j+1; k < n0; k++)
82                 {
83                     int x = i,y = j,z = k;
84
85                     if ((p[z] - p[x]) * (p[y] - p[x]) > 0)
86                         swap(y, z);

```

```

87         int res = cntleft[x][z] + cntleft[z][y] +
            cntleft[y][x];
88
89         res += calc(x, y, z) + calc(y, z, x) + calc(z,
            x, y);
90
91         res -= 2 * n1;
92
93         //printf("%d %d %d %d\n",x,y,z,res);
94
95         if (res%2 == 1)
96             ans++;
97     }
98     printf("Case_□%d:□%d\n",++cas,ans);
99 }
100 return 0;
101 }

```

7.12 最近点对

7.12.1 类快排算法

```

1 double calc_dis(Point &a ,Point &b) {
2     return sqrt((a.x-b.x)*(a.x-b.x) + (a.y-b.y)*(a.y-b.y));
3 }
4 //别忘了排序
5 bool operator<(const Point &a ,const Point &b) {
6     if(a.y != b.y) return a.x < b.x;
7     return a.x < b.x;
8 }
9 double Gao(int l ,int r ,Point pnts[]) {
10     double ret = inf;
11     if(l == r) return ret;
12     if(l+1 ==r) {
13         ret = min(calc_dis(pnts[l],pnts[l+1]) ,ret);
14         return ret;
15     }
16     if(l+2 ==r) {
17         ret = min(calc_dis(pnts[l],pnts[l+1]) ,ret);
18         ret = min(calc_dis(pnts[l],pnts[l+2]) ,ret);
19         ret = min(calc_dis(pnts[l+1],pnts[l+2]) ,ret);
20         return ret;
21     }
22
23     int mid = l+r>>1;
24     ret = min (ret ,Gao(l ,mid,pnts));
25     ret = min (ret , Gao(mid+1, r,pnts));
26
27     for(int c = l ; c<=r; c++)
28         for(int d = c+1; d <=c+7 && d<=r; d++) {
29             ret = min(ret , calc_dis(pnts[c],pnts[d]));
30         }

```

```

31     return ret;
32 }

```

7.12.2 随机增量法

```

1  #include <iostream>
2  #include <cstdio>
3  #include <cstring>
4  #include <map>
5  #include <vector>
6  #include <cmath>
7  #include <algorithm>
8  #define Point pair<double,double>
9  using namespace std;
10
11 const int step[9][2] =
12     {{-1,-1},{-1,0},{-1,1},{0,-1},{0,0},{0,1},{1,-1},{1,0},{1,1}};
13 int n,x,y,nx,ny;
14 map<pair<int,int>,vector<Point > > g;
15 vector<Point > tmp;
16 Point p[20000];
17 double tx,ty,ans,nowans;
18 vector<Point >::iterator it,op,ed;
19 pair<int,int> gird;
20 bool flag;
21
22 double Dis(Point p0,Point p1)
23 {
24     return sqrt((p0.first-p1.first)*(p0.first-p1.first)+
25                 (p0.second-p1.second)*(p0.second-p1.second));
26 }
27
28 double CalcDis(Point p0,Point p1,Point p2)
29 {
30     return Dis(p0,p1)+Dis(p0,p2)+Dis(p1,p2);
31 }
32
33 void build(int n,double w)
34 {
35     g.clear();
36     for (int i = 0;i < n;i++)
37         g[make_pair((int)floor(p[i].first/w),(int)floor(p[i].second
38                     /w))].push_back(p[i]);
39 }
40
41 int main()
42 {
43     int t;
44     scanf("%d",&t);
45     for (int ft = 1;ft <= t;ft++)
46     {
47         scanf("%d",&n);

```

```

46     for (int i = 0; i < n; i++)
47     {
48         scanf("%lf%lf", &tx, &ty);
49         p[i] = make_pair(tx, ty);
50     }
51     random_shuffle(p, p+n);
52     ans = CalcDis(p[0], p[1], p[2]);
53     build(3, ans/2.0);
54     for (int i = 3; i < n; i++)
55     {
56         x = (int)floor(2.0*p[i].first/ans);
57         y = (int)floor(2.0*p[i].second/ans);
58         tmp.clear();
59         for (int k = 0; k < 9; k++)
60         {
61             nx = x+step[k][0];
62             ny = y+step[k][1];
63             gird = make_pair(nx, ny);
64             if (g.find(gird) != g.end())
65             {
66                 op = g[gird].begin();
67                 ed = g[gird].end();
68                 for (it = op; it != ed; it++)
69                     tmp.push_back(*it);
70             }
71         }
72         flag = false;
73         for (int j = 0; j < tmp.size(); j++)
74             for (int k = j+1; k < tmp.size(); k++)
75             {
76                 nowans = CalcDis(p[i], tmp[j], tmp[k]);
77                 if (nowans < ans)
78                 {
79                     ans = nowans;
80                     flag = true;
81                 }
82             }
83         if (flag == true)
84             build(i+1, ans/2.0);
85         else
86             g[make_pair((int)floor(2.0*p[i].first/ans), (int)
87                         floor(2.0*p[i].second/ans))].push_back(p[i]);
88     }
89     printf("%.3f\n", ans);
90 }

```

7.13 多圆面积并

7.13.1 去重

有时候可能需要去掉不需要的圆


```

1 for (int i = 0; i < n; i++)
2 {
3     scanf("%lf%lf%lf",&c[i].c.x,&c[i].c.y,&c[i].r);
4     del[i] = false;
5 }
6 for (int i = 0; i < n; i++)
7     if (del[i] == false)
8     {
9         if (c[i].r == 0.0) del[i] = true;
10        for (int j = 0; j < n; j++)
11            if (i != j)
12                if (del[j] == false)
13                    if (cmp(Point(c[i].c,c[j].c).Len()+c[i].r,c[j].
14                        r) <= 0)
15                        del[i] = true;
16    }
17    tn = n;
18    n = 0;
19    for (int i = 0; i < tn; i++)
20        if (del[i] == false)
21            c[n++] = c[i];

```

7.13.2 圆并

$ans[i]$ 表示被覆盖 i 次的面积

```

1 const double pi = acos(-1.0);
2 const double eps = 1e-8;
3 struct Point
4 {
5     double x,y;
6     Point(){}
7     Point(double _x,double _y)
8     {
9         x = _x;
10        y = _y;
11    }
12    double Length()
13    {
14        return sqrt(x*x+y*y);
15    }
16 };
17 struct Circle
18 {
19     Point c;
20     double r;
21 };
22 struct Event
23 {
24     double tim;
25     int typ;
26     Event(){}

```

```

27     Event(double _tim,int _typ)
28     {
29         tim = _tim;
30         typ = _typ;
31     }
32 };
33
34 int cmp(const double& a,const double& b)
35 {
36     if (fabs(a-b) < eps)    return 0;
37     if (a < b)    return -1;
38     return 1;
39 }
40
41 bool Eventcmp(const Event& a,const Event& b)
42 {
43     return cmp(a.tim,b.tim) < 0;
44 }
45
46 double Area(double theta,double r)
47 {
48     return 0.5*r*r*(theta-sin(theta));
49 }
50
51 double xmult(Point a,Point b)
52 {
53     return a.x*b.y-a.y*b.x;
54 }
55
56 int n,cur,tote;
57 Circle c[1000];
58 double ans[1001],pre[1001],AB,AC,BC,theta,fai,a0,a1;
59 Event e[4000];
60 Point lab;
61
62 int main()
63 {
64     while (scanf("%d",&n) != EOF)
65     {
66         for (int i = 0;i < n;i++)
67             scanf("%lf%lf%lf",&c[i].c.x,&c[i].c.y,&c[i].r);
68         for (int i = 1;i <= n;i++)
69             ans[i] = 0.0;
70         for (int i = 0;i < n;i++)
71         {
72             tote = 0;
73             e[tote++] = Event(-pi,1);
74             e[tote++] = Event(pi,-1);
75             for (int j = 0;j < n;j++)
76                 if (j != i)
77                     {

```

```

78         lab = Point(c[j].c.x-c[i].c.x,c[j].c.y-c[i].c.y
79             );
80         AB = lab.Length();
81         AC = c[i].r;
82         BC = c[j].r;
83         if (cmp(AB+AC,BC) <= 0)
84         {
85             e[tote++] = Event(-pi,1);
86             e[tote++] = Event(pi,-1);
87             continue;
88         }
89         if (cmp(AB+BC,AC) <= 0) continue;
90         if (cmp(AB,AC+BC) > 0) continue;
91         theta = atan2(lab.y,lab.x);
92         fai = acos((AC*AC+AB*AB-BC*BC)/(2.0*AC*AB));
93         a0 = theta-fai;
94         if (cmp(a0,-pi) < 0)      a0 += 2*pi;
95         a1 = theta+fai;
96         if (cmp(a1,pi) > 0)      a1 -= 2*pi;
97         if (cmp(a0,a1) > 0)
98         {
99             e[tote++] = Event(a0,1);
100            e[tote++] = Event(pi,-1);
101            e[tote++] = Event(-pi,1);
102            e[tote++] = Event(a1,-1);
103        }
104        else
105        {
106            e[tote++] = Event(a0,1);
107            e[tote++] = Event(a1,-1);
108        }
109    }
110    sort(e,e+tote,Eventcmp);
111    cur = 0;
112    for (int j = 0;j < tote;j++)
113    {
114        if (cur != 0 && cmp(e[j].tim,pre[cur]) != 0)
115        {
116            ans[cur] += Area(e[j].tim-pre[cur],c[i].r);
117            ans[cur] += xmult(Point(c[i].c.x+c[i].r*cos(pre
118                [cur]),c[i].c.y+c[i].r*sin(pre[cur])),
119                Point(c[i].c.x+c[i].r*cos(e
120                    [j].tim),c[i].c.y+c[i].r
121                    *sin(e[j].tim)))/2.0;
122        }
123        cur += e[j].typ;
124        pre[cur] = e[j].tim;
125    }
126    }
127    for (int i = 1;i < n;i++)
128        ans[i] -= ans[i+1];

```

```

125     for (int i = 1; i <= n; i++)
126         printf("[%d]□=□%.3f\n", i, ans[i]);
127     }
128     return 0;
129 }

```

7.14 一个圆与多边形面积交

```

1 bool InCircle(Point a, double r)
2 {
3     return cmp(a.x*a.x+a.y*a.y, r*r) <= 0; //这里判断的时候EPS一定不要太
        小!!
4 }
5
6 double CalcArea(Point a, Point b, double r)
7 {
8     Point p[4];
9     int tot = 0;
10    p[tot++] = a;
11
12    Point tv = Point(a, b);
13    Line tmp = Line(Point(0, 0), Point(tv.y, -tv.x));
14    Point near = LineToLine(Line(a, b), tmp);
15    if (cmp(near.x*near.x+near.y*near.y, r*r) <= 0)
16    {
17        double A, B, C;
18        A = near.x*near.x+near.y*near.y;
19        C = r;
20        B = C*C-A;
21        double tvl = tv.x*tv.x+tv.y*tv.y;
22        double tmp = sqrt(B/tvl); //这样做只用一次开根
23        p[tot] = Point(near.x+tmp*tv.x, near.y+tmp*tv.y);
24        if (OnSeg(Line(a, b), p[tot]) == true) tot++;
25        p[tot] = Point(near.x-tmp*tv.x, near.y-tmp*tv.y);
26        if (OnSeg(Line(a, b), p[tot]) == true) tot++;
27    }
28    if (tot == 3)
29    {
30        if (cmp(Point(p[0], p[1]).Length(), Point(p[0], p[2]).Length())
            > 0)
31            swap(p[1], p[2]);
32    }
33    p[tot++] = b;
34
35    double res = 0.0, theta, a0, a1, sgn;
36    for (int i = 0; i < tot-1; i++)
37    {
38        if (InCircle(p[i], r) == true && InCircle(p[i+1], r) == true)
39        {
40            res += 0.5*xmult(p[i], p[i+1]);

```

```

41     }
42     else
43     {
44         a0 = atan2(p[i+1].y,p[i+1].x);
45         a1 = atan2(p[i].y,p[i].x);
46         if (a0 < a1)      a0 += 2*pi;
47         theta = a0-a1;
48         if (cmp(theta,pi) >= 0) theta = 2*pi-theta;
49         sgn = xmult(p[i],p[i+1])/2.0;
50         if (cmp(sgn,0) < 0) theta = -theta;
51         res += 0.5*r*r*theta;
52     }
53 }
54 return res;
55 }

```

调用

```

1 area2 = 0.0;
2 for (int i = 0;i < resn;i++) //遍历每条边, 按照逆时针
3     area2 += CalcArea(p[i],p[(i+1)%resn],r);

```

7.15 精度问题

7.15.1 浮点数为啥会有精度问题

浮点数(以C/C++为准), 一般用的较多的是float、double。

	占字节数	数值范围	十进制精度位数
float	4	$-3.4e-38 \sim 3.4e38$	6 ~ 7
double	8	$-1.7e-308 \sim 1.7e308$	14 ~ 15

如果内存不是很紧张或者精度要求不是很低, 一般选用double。14位的精度(是有效数字位, 不是小数点后的位数)通常够用了。注意, 问题来了, 数据精度位数达到了14位, 但有些浮点运算的结果精度并达不到这么高, 可能准确的结果只有10 ~ 12位左右。那低几位呢? 自然就是不可预料的数字了。这给我们带来这样的问题: 即使是理论上相同的值, 由于是经过不同的运算过程得到的, 他们在低几位有可能(一般来说都是)是不同的。这种现象看似没太大的影响, 却会一种运算产生致命的影响: `==`。恩, 就是判断相等。注意, C/C++中浮点数的`==`需要完全一样才能返回true。

7.15.2 eps

eps缩写自epsilon, 表示一个小量, 但这个量又要确保远大于浮点运算结果的不确定量。eps最常见的取值是 $1e-8$ 左右。引入eps后, 我们判断两浮点数a、b相等的方式如下:

```

1 int sgn(double a){return a < -eps ? -1 : a < eps ? 0 : 1;}

```

这样, 我们才能把相差非常近的浮点数判为相等; 同时把确实相差较大(差值大于eps)的数判为不相等。

养成好习惯, 尽量不要再对浮点数做`==`判断。

7.15.3 eps带来的函数越界

如果 $\text{sqrt}(a)$, $\text{asin}(a)$, $\text{acos}(a)$ 中的 a 是你自己算出来并传进来的, 那就得小心了。

如果 a 本来应该是0的, 由于浮点误差, 可能实际是一个绝对值很小的负数 (比如 $-1e-12$), 这样 $\text{sqrt}(a)$ 应得0的, 直接因 a 不在定义域而出错。

类似地, 如果 a 本来应该是 ± 1 , 则 $\text{asin}(a)$ 、 $\text{acos}(a)$ 也有可能出错。

因此, 对于此种函数, 必需事先对 a 进行校正。

7.15.4 输出陷阱I

现在考虑一种情况, 题目要求输出保留两位小数。有个case的正确答案的精确值是0.005, 按理应该输出0.01, 但你的结果可能是0.005000000001(恭喜), 也有可能是0.004999999999(悲剧), 如果按照`printf("%.2lf", a)`输出, 那你的遭遇将和括号里的字相同。

解决办法是, 如果 a 为正, 则输出 $a + \text{eps}$, 否则输出 $a - \text{eps}$

7.15.5 输出陷阱II

ICPC题目输出有个不成文的规定(有时也成文), 不要输出: -0.000

那我们首先要弄清, 什么时候按`printf("%.3lf", a)`输出会出现这个结果。

直接给出结果好了: $a \in (-0.000499999 \dots, -0.000 \dots 1)$

所以, 如果你发现 a 落在这个范围内, 请直接输出0.000。更保险的做法是用`sprintf`直接判断输出结果是不是 -0.000 再予处理。

7.15.6 范围越界

请注意, 虽然`double`可以表示的数的范围很大, 却不是无穷大, 上面说过最大是 $1e308$ 。所以有些时候你得小心了, 比如做连乘的时候, 必要的时候要换成对数的和。

7.15.7 关于set

经观察, `set`不是通过`==`来判断相等的, 是通过`<`来进行的, 具体说来, 只要 $a < b$ 和 $b < a$ 都不成立, 就认为 a 和 b 相等, 可以发现, 如果将小于定义成:

```
1 | bool operator < (const Dat dat) const { return val < dat.val - eps; }
```

就可以解决问题了。(基本类型不能重载运算符, 所以封装了下)

7.15.8 输入值波动过大

这种情况不常见, 不过可以帮助你更熟悉`eps`。假如一道题输入说, 给一个浮点数 a , $1e-20 < a < 1e20$ 。那你还敢用 $1e-8$ 做`eps`么? 合理的做法是把`eps`按照输入规模缩放到合适大小。

7.15.9 一些建议

容易产生较大浮点误差的函数有`asin`、`acos`。欢迎尽量使用`atan2`。

另外, 如果数据明确说明是整数, 而且范围不大的话, 使用`int`或者`long long`代替`double`都是极佳选择, 因为就不存在浮点误差了

8 搜索

8.1 Dancing Links

8.1.1 估价函数

```

1 int h()
2 {
3     bool vis[100];
4     memset(vis,false,sizeof(vis));
5     int i,j,k,res=0,mi,col;
6     while(1)
7     {
8         mi=inf;
9         for(i=R[head]; i!=head&&i<=2*n; i=R[i])
10             if(mi>nk[i]&&!vis[i])
11                 {
12                     mi=nk[i];
13                     col=i;
14                 }
15         if(mi==inf)
16             break;
17         res++;
18         vis[col]=true;
19         for(j=D[col]; j!=col; j=D[j])
20             for(k=R[j]; k!=j; k=R[k])
21                 {
22                     if(C[k]>2*n)
23                         continue;
24                     vis[C[k]]=true;
25                 }
26     }
27     return res;
28 }
```

8.1.2 DLX

```

1 void remove1(int col)
2 {
3     int i,j;
4     L[R[col]]=L[col];
5     R[L[col]]=R[col];
6     for(i=D[col]; i!=col; i=D[i])
7     {
8         L[R[i]]=L[i];
9         R[L[i]]=R[i];
10    }
11 }
12 void remove2(int col)
13 {
14     int i,j;
15     L[R[col]]=L[col];
```

```

16     R[L[col]]=R[col];
17     for(i=D[col];i!=col;i=D[i])
18     {
19         for(j=R[i];j!=i;j=R[j])
20         {
21             U[D[j]]=U[j];
22             D[U[j]]=D[j];
23             --nk[C[j]];
24         }
25     }
26 }
27 void resume1(int col)
28 {
29     int i,j;
30     for(i=U[col];i!=col;i=U[i])
31     {
32         L[R[i]]=i;
33         R[L[i]]=i;
34     }
35     L[R[col]]=col;
36     R[L[col]]=col;
37 }
38 void resume2(int col)
39 {
40     int i,j;
41     for(i=U[col];i!=col;i=U[i])
42     {
43         for(j=L[i];j!=i;j=L[j])
44         {
45             ++nk[C[j]];
46             U[D[j]]=j;
47             D[U[j]]=j;
48         }
49     }
50     L[R[col]]=col;
51     R[L[col]]=col;
52 }
53 int h()
54 {
55     bool vis[100];
56     memset(vis,false,sizeof(vis));
57     int i,j,k,res=0,mi,col;
58     while(1)
59     {
60         mi=inf;
61         for(i=R[head];i!=head&&i<=2*n;i=R[i])
62             if(mi>nk[i]&&!vis[i])
63             {
64                 mi=nk[i];
65                 col=i;
66             }

```



```

67     if(mi==inf)
68         break;
69     res++;vis[col]=true;
70     for(j=D[col];j!=col;j=D[j])
71         for(k=R[j];k!=j;k=R[k])
72             {
73                 if(C[k]>2*n)
74                     continue;
75                 vis[C[k]]=true;
76             }
77     }
78     return res;
79 }
80 bool DLX(int d,int deep)
81 {
82     if(d+h(>deep) return false;
83     if(R[head]==head||R[head]>2*n)
84         return true;
85     if(d>=deep)
86         return false;
87     int col,ma=inf;
88     int i,j;
89     for(i=R[head];i!=head&&i<=2*n;i=R[i])
90         if(nk[i]<ma)
91             {
92                 col=i;
93                 ma=nk[i];
94             }
95     remove1(col);
96     for(i=D[col];i!=col;i=D[i])
97     {
98         int flag=1;
99         for(j=R[i];j=R[j])
100             {
101                 if(j==R[i]&&!flag)
102                     break;
103                 U[D[j]]=U[j];
104                 D[U[j]]=D[j];
105                 if(C[j]>2*n)
106                     remove2(C[j]);
107                 else
108                     remove1(C[j]);
109                 flag=0;
110             }
111         if(DLX(d+1,deep))
112             return true;
113         flag=1;
114         for(j=L[i];j=L[j])
115             {
116                 if(j==L[i]&&!flag)
117                     break;

```

```
118         if(C[j]>2*n)
119             resume2(C[j]);
120         else
121             resume1(C[j]);
122         U[D[j]]=j;
123         D[U[j]]=j;
124         flag=0;
125     }
126 }
127 resume1(col);
128 return false;
129 }
```

9 动态规划

9.1 斜率优化

```

1  #include<cstdio>
2  #include<algorithm>
3  using namespace std;
4  int a[1000],sum[1001],dp[1000][1000];
5  int deque[1000];
6  const int inf=0x7fffffff;
7  int N,s,t;
8  int calc(int i,int l,int j)//决策值计算
9  {
10     return dp[j][l-1]-(sum[i]-sum[j])*(sum[N]-sum[i]);
11 }
12 bool check(int i,int l)//尾端判断
13 {
14     int k1=deque[t-1],k2=deque[t-2];
15     return (long long)(dp[k1][l]-dp[k2][l])*(sum[i]-sum[k1])>(long
        long)(dp[i][l]-dp[k1][l])*(sum[k1]-sum[k2]);
16 }
17 int main()
18 {
19     int n,m;
20     while (scanf("%d%d",&n,&m),n)
21     {
22         for (int i=0; i<n; i++)
23             scanf("%d",&a[i]);
24         N=n;
25         sum[0]=0;
26         for (int i=0; i<n; i++)
27             sum[i+1]=sum[i]+a[i];
28         dp[0][0]=0;
29         for (int i=0; i<n; i++)
30             for (int j=i+1; j<n; j++)
31                 dp[0][0]+=a[i]*a[j];
32         for (int i=1; i<n; i++)
33             dp[i][0]=inf;
34         for (int i=1; i<n; i++)
35         {
36             dp[i][1]=inf;
37             for (int j=0; j<i; j++)
38                 dp[i][1]=min(dp[i][1],calc(i,1,j));
39         }
40         for (int l=2; l<=m; l++)
41         {
42             s=t=0;//双端队列清空
43             for (int i=1; i<n; i++)
44             {
45                 while (t-s>1 && check(i-1,l-1)) t--;
46                 deque[t++]=i-1;//决策加入

```

```

47         while (t-s>1 && calc(i,l,deque[s])>calc(i,l,deque[s
           +1])) s++;
48         dp[i][l]=calc(i,l,deque[s]);
49     }
50 }
51 int ans=0x7fffffff;
52 for (int i=m; i<n; i++)
53     ans=min(ans,dp[i][m]);
54 printf("%d\n",ans);
55 }
56 return 0;
57 }

```

9.2 RMQ二版

```

1 void init()
2 {
3     int i,j;
4     int n=N,k=1,l=0;
5     for (i=0; i<n; i++)
6     {
7         f[i][0]=ele[i].num;
8         if (i+1>k*2)
9         {
10             k*=2;
11             l++;
12         }
13         lent[i+1]=l;
14     }
15     for (j=1; (1<<j)-1<n; j++)
16         for (i=0; i+(1<<j)-1<n; i++)
17             f[i][j]=max(f[i][j-1],f[i+(1<<(j-1))][j-1]);
18 }
19 int fint(int x,int y)
20 {
21     int k=lent[y-x+1];
22     return max(f[x][k],f[y-(1<<k)+1][k]);
23 }

```

9.3 二维LIS

```

1 #include<cstdio>
2 #include<map>
3 using namespace std;
4 map<int,int> mp[100001];
5 bool check(int idx,int x,int y)
6 {
7     if (!idx) return 1;
8     if (mp[idx].begin()->first>=x) return 0;
9     map<int,int> ::iterator it=mp[idx].lower_bound(x);
10    it--;
11    if (it->second<y) return 1;

```

```

12     else return 0;
13 }
14 int main()
15 {
16     int n;
17     scanf("%d",&n);
18     int l=0,r=0;
19     for (int i=0;i<n;i++)
20     {
21         int x,y;
22         scanf("%d%d",&x,&y);
23         int tl=l,tr=r;
24         while (tl<tr)
25         {
26             int mid=(tl+tr+1)/2;
27             if (check(mid,x,y))
28                 tl=mid;
29             else
30                 tr=mid-1;
31         }
32         if (tl==r) r++;
33         int idx=tl+1;
34         map<int,int> ::iterator itl=mp[idx].lower_bound(x),itr=itl;
35         while (itr!=mp[idx].end() && itr->second>y) itr++;
36         if (mp[idx].find(x)!=mp[idx].end())
37             y=min(y,mp[idx][x]);
38         if (itl!=itr) mp[idx].erase(itl,itr);
39         if (mp[idx].find(x)==mp[idx].end() || mp[idx][x]>y)
40             mp[idx][x]=y;
41     }
42     printf("%d\n",r);
43     return 0;
44 }

```

9.4 插头DP

Tower Defence独立插头+构造解

构造解的时候保存的是在hash_map的ele数组的下标位置

没想清楚千万别去写

```

1 int bit[12];
2
3 inline int getbit(long long sta,int pos)
4 {
5     return sta/bit[pos]%bit[1];
6 }
7
8 inline long long setbit(long long sta,int pos,int val)
9 {
10     return sta/bit[pos+1]*bit[pos+1]+val*bit[pos]+sta%bit[pos];
11 }
12

```

```

13 int n,m,mp[30][10];
14 char buf[30][10];
15 hash_map dp[2];
16 bool flag;
17 int key,val,upd,l,u,res,msk,cov,now,pr,resnow,resmsk,pru;
18 int w[15],s[15],top;
19 int pre[210][10007],preuse[210][10007];
20
21 void decode(int msk,int& key,int& cov)
22 {
23     int tmp;
24     key = cov = 0;
25     for (int i = 0; i < m+1; i++)
26     {
27         tmp = getbit(msk,i);
28         if (tmp > 0)
29         {
30             key = setbit(key,i,tmp-1);
31             cov = setbit(cov,i,1);
32         }
33     }
34 }
35
36 int encode(int key,int cov)
37 {
38     int res = 0,tmp;
39     for (int i = 0; i < m+1; i++)
40     {
41         tmp = getbit(cov,i);
42         if (tmp > 0)
43         {
44             tmp = getbit(key,i);
45             res = setbit(res,i,tmp+1);
46         }
47     }
48     return res;
49 }
50
51 void update(int a,int key,int cov,int val)
52 {
53     int msk = encode(key,cov);
54     int pos;
55     if (dp[a][msk] < val)
56     {
57         dp[a][msk] = val;
58         pos = dp[a].fint(msk);
59         pre[now][pos] = pr;
60         preuse[now][pos] = pru;
61     }
62 }
63

```

```

64 int count3(int sta)
65 {
66     int res = 0;
67     for (int i = 0; i < m+1; i++)
68         if (getbit(sta,i) == 3)
69             res++;
70     return res;
71 }
72
73 void expand(int sta)
74 {
75     top = 0;
76     for (int i = 0; i < m+1; i++)
77         if (getbit(sta,i) == 1)
78             s[top++] = i;
79         else if (getbit(sta,i) == 2)
80         {
81             w[s[top-1]] = i;
82             w[i] = s[top-1];
83             top--;
84         }
85 }
86
87 int main()
88 {
89     //freopen("TD.in","r",stdin);
90     //freopen("TDM.out","w",stdout);
91     bit[0] = 1;
92     for (int i = 1; i < 12; i++)    bit[i] = bit[i-1]*5;
93     int t;
94     scanf("%d",&t);
95     dp[0].init();
96     dp[1].init();
97     for (int ft = 1; ft <= t; ft++)
98     {
99         scanf("%d%d",&n,&m);
100         res = 0;
101         memset(mp,0,sizeof(mp));
102         memset(pre,0,sizeof(pre));
103         memset(preuse,0,sizeof(preuse));
104         for (int i = 0; i < n; i++)
105         {
106             scanf("%s",buf[i]);
107             for (int j = 0; j < m; j++)
108                 if (buf[i][j] == '.')
109                     mp[i][j] = 1;
110                 else if (buf[i][j] != 'B')
111                     mp[i][j] = 2;
112         }
113         dp[0].clear();
114         dp[1].clear();

```

```

115     flag = 0;
116     dp[flag][0] = 0;
117     int res = 0;
118     now = 0;
119     for (int i = 0; i < n; i++)
120     {
121         for (int j = 0; j < m; j++)
122         {
123             dp[!flag].clear();
124             for (int k = 0; k < dp[flag].N; k++)
125             {
126                 msk = dp[flag].ele[k].key;
127                 pr = k;
128                 val = dp[flag].ele[k].val;
129                 decode(msk, key, cov);
130                 l = getbit(key, j);
131                 u = getbit(key, j+1);
132                 if (mp[i][j] == 0) //是障碍
133                 {
134                     if (l == 0 && u == 0)
135                     {
136                         pru = 0;
137                         update(!flag, key, setbit(setbit(cov, j, 0),
138                                     j+1, 0), val);
139                     }
140                     else
141                     {
142                         if (mp[i][j] == 1 && l == 0 && u == 0) //不
143                             要插头
144                         {
145                             pru = 1;
146                             update(!flag, key, setbit(setbit(cov, j, 0),
147                                     j+1, 0), val);
148                         }
149                         if (getbit(cov, j) == 1 && l == 0)
150                             continue; //不可以在这里搞插
151                             头
152                         if (getbit(cov, j+1) == 1 && u == 0)
153                             continue;
154                         cov = setbit(setbit(cov, j, 1), j+1, 1); //更新覆
155                             盖情况
156                         upd = setbit(setbit(key, j, 0), j+1, 0);
157                         pru = 2;
158                         if (mp[i][j] == 2)
159                         {
160                             if (l == 0 && u == 0)
161                             {
162                                 if (count3(key) < 2) //可以新建独立插头
163                                 {
164                                     if (mp[i][j+1] != 0)

```



```

159         update(!flag, setbit(setbit(
160             key, j, 0), j+1, 3), cov, val
161             +1);
162     }
163 }
164 else if (l == 0 || u == 0)
165 {
166     if (l+u < 3 && count3(key) < 2) //可
        以用一个独立插头来结束这条路径
167     {
168         expand(key);
169         if (l > 0)
170             update(!flag, setbit(upd, w[j]
171                 ], 3), cov, val+1);
172         else
173             update(!flag, setbit(upd, w[j
174                 +1], 3), cov, val+1);
175     }
176     else if (l+u == 3 && upd == 0) //路
        径的一端
177     {
178         if (res < val+1)
179         {
180             res = val+1;
181             resnow = now-1;
182             resmsk = k;
183         }
184     }
185 }
186 else if (l == 0 && u == 0)
187 {
188     if (mp[i][j+1] != 0 && mp[i+1][j] != 0)
        //可以新建插
        头
189         update(!flag, setbit(setbit(key, j, 1)
190             , j+1, 2), cov, val+1);
191 }
192 else if (l == 0 || u == 0)
193 {
194     if (mp[i][j+1] != 0) //可以延续插头
195         update(!flag, setbit(upd, j+1, l+u),
196             cov, val+1);
197     if (mp[i+1][j] != 0) //可以延续插头
198         update(!flag, setbit(upd, j, l+u), cov,
199             val+1);
200 }

```

```

197         else if (l == u)
198         {
199             if (l < 3) //合并两个相同的括号
200             {
201                 expand(key);
202                 if (l == 1)
203                     update(!flag, setbit(upd, w[j]
204                                     + 1], 1), cov, val+1);
205                 else
206                     update(!flag, setbit(upd, w[j], 2)
207                             , cov, val+1);
208             }
209             else if (upd == 0) //合并两个独立插头
210             {
211                 if (res < val+1)
212                 {
213                     res = val+1;
214                     resnow = now-1;
215                     resmsk = k;
216                 }
217             }
218             else if (l == 3 || u == 3) //合并独立插头与括号
219             {
220                 expand(key);
221                 if (l == 3)
222                     update(!flag, setbit(upd, w[j+1], 3),
223                             cov, val+1);
224                 else
225                     update(!flag, setbit(upd, w[j], 3), cov
226                             , val+1);
227             }
228             else if (l == 2 || u == 1) //合并)(
229                 update(!flag, upd, cov, val+1);
230         }
231     }
232     flag = !flag;
233     now++;
234     if (i+1 == n) break;
235     dp[!flag].clear();
236     for (int k = 0; k < dp[flag].N; k++)
237     {
238         msk = dp[flag].ele[k].key;
239         pr = k;
240         val = dp[flag].ele[k].val;
241         pr = 0;
242         decode(msk, key, cov);
243         update(!flag, key*bit[1], cov*bit[1], val);
244     }

```

```
244         now++;
245         flag = !flag;
246     }
247
248     printf("Case_□%d:□%d\n",ft,res);
249     for (int i = resnow; i >= 0; i--)
250     {
251         if (preuse[i][resmsk] == 1)
252             buf[i/(m+1)][i%(m+1)] = 'W';
253         resmsk = pre[i][resmsk];
254     }
255     for (int i = 0; i < n; i++)
256         printf("%s\n",buf[i]);
257     printf("\n");
258 }
259 return 0;
260 }
```

10 杂物

10.1 高精度数

支持乘以整数和加法。

```

1 struct BigInt
2 {
3     const static int mod = 1000000000;
4     int a[600], len;
5     BigInt () {}
6     BigInt (int v)
7     {
8         len = 0;
9         do
10        {
11            a[len++] = v%mod;
12            v /= mod;
13        }while(v);
14    }
15    BigInt operator *(const int& b) const
16    {
17        BigInt res;
18        res.len = len;
19        for (int i = 0; i <= len; ++i)
20            res.a[i] = 0;
21        for (int i = 0; i < len; ++i)
22        {
23            res.a[i] += a[i]*b;
24            res.a[i+1] += res.a[i]/mod;
25            res.a[i] %= mod;
26        }
27        if (res.a[len] > 0) res.len++;
28        return res;
29    }
30    BigInt operator +(const BigInt& b) const
31    {
32        BigInt res;
33        res.len = max(len, b.len);
34        for (int i = 0; i <= res.len; ++i)
35            res.a[i] = 0;
36        for (int i = 0; i < res.len; ++i)
37        {
38            res.a[i] += ((i < len)?a[i]:0)+((i < b.len)?b.a[i]:0);
39            res.a[i+1] += res.a[i]/mod;
40            res.a[i] %= mod;
41        }
42        if (res.a[res.len] > 0) res.len++;
43        return res;
44    }
45    void output()

```

```

46     {
47         printf("%d",a[len-1]);
48         for (int i = len-2; i >= 0; --i)
49             printf("%08d",a[i]);
50         printf("\n");
51     }
52 };

```

10.2 整数外挂

```

1  int wg;
2  char ch;
3  bool ng;
4
5  inline int readint()
6  {
7      ch = getchar();
8      while (ch != '-' && (ch < '0' || ch > '9')) ch = getchar();
9      if (ch == '-')
10     {
11         ng = true;
12         ch = getchar();
13     }
14     else
15         ng = false;
16     wg = ch-'0';
17     ch = getchar();
18     while (ch >= '0' && ch <= '9')
19     {
20         wg = wg*10+ch-'0';
21         ch = getchar();
22     }
23     if (ng == true) wg = -wg;
24     return wg;
25 }

```

10.3 Java

10.3.1 文件操作

```

1  import java.io.*;
2  import java.util.*;
3  import java.math.*;
4  import java.text.*;
5
6  public class Main
7  {
8
9      public static void main(String args[]) throws
10         FileNotFoundException, IOException
11     {
12         Scanner sc = new Scanner(new FileReader("a.in"));

```

```

12     PrintWriter pw = new PrintWriter(new FileWriter("a.out"));
13     int n,m;
14     n=sc.nextInt();//读入下一个INT
15     m=sc.nextInt();
16
17     for(ci=1; ci<=c; ++ci)
18     {
19         pw.println("Case_#"+ci+":_easy_for_output");
20     }
21
22     pw.close();//关闭流并释放, 这个很重要, 否则是没有输出的
23     sc.close();//关闭流并释放
24 }
25 }

```

10.3.2 优先队列

```

1 PriorityQueue queue = new PriorityQueue( 1, new Comparator()
2 {
3     public int compare( Point a, Point b )
4     {
5         if( a.x < b.x || a.x == b.x && a.y < b.y )
6             return -1;
7         else if( a.x == b.x && a.y == b.y )
8             return 0;
9         else
10             return 1;
11     }
12 });

```

10.3.3 Map

```

1 Map map = new HashMap();
2 map.put("sa","dd");
3 String str = map.get("sa").toString;
4
5 for(Object obj : map.keySet()){
6     Object value = map.get(obj );
7 }

```

10.3.4 sort

```

1 static class cmp implements Comparator
2 {
3     public int compare(Object o1,Object o2)
4     {
5         BigInteger b1=(BigInteger)o1;
6         BigInteger b2=(BigInteger)o2;
7         return b1.compareTo(b2);
8     }
9 }
10 public static void main(String[] args) throws IOException
11 {

```

```

12     Scanner cin = new Scanner(System.in);
13     int n;
14     n=cin.nextInt();
15     BigInteger[] seg = new BigInteger[n];
16     for (int i=0;i<n;i++)
17     seg[i]=cin.nextBigInteger();
18     Arrays.sort(seg,new cmp());
19 }

```

10.4 hashmap

```

1 struct hash_map
2 {
3     const static int mod=10007;
4     int head[mod];
5     struct hash_tables
6     {
7         int key;
8         int val;
9         int next;
10    } ele[10007];
11    int N;
12    int getHash(int x)
13    {
14        return x%mod;
15    }
16    void init()
17    {
18        memset(head,255,sizeof(head));
19        N=0;
20    }
21    void clear()
22    {
23        for (int i = 0; i < N; i++)
24            head[getHash(ele[i].key)] = -1;
25        N = 0;
26    }
27    int fint(int x)
28    {
29        for (int i=head[getHash(x)]; i!=-1; i=ele[i].next)
30            if (ele[i].key==x) return i;
31        return -1;
32    }
33    void insert(int x)
34    {
35        int tmp=getHash(x);
36        ele[N].key=x;
37        ele[N].val=0;
38        ele[N].next=head[tmp];
39        head[tmp]=N++;
40    }
41    int& operator [] (int x)

```

```

42     {
43         int tmp=fint(x);
44         if (tmp==-1)
45         {
46             insert(x);
47             return ele[N-1].val;
48         }
49         else
50             return ele[tmp].val;
51     }
52 };

```

10.5 C++&STL常用函数

10.5.1 lower_bound/upper_bound

不解释

```

1 | iterator lower_bound(const key_type &key )\\返回一个迭代器，指向键值>=
   | key的第一个元素。
2 | iterator upper_bound(const key_type &key )\\返回一个迭代器，指向键值>
   | key的第一个元素。
3 |
4 | #include <iostream>
5 | #include <algorithm>
6 | #include <vector>
7 | using namespace std;
8 |
9 | int main () {
10 |     int myints[] = {10,20,30,30,20,10,10,20};
11 |     vector<int> v(myints,myints+8);           // 10 20 30 30 20 10 10
        20
12 |     vector<int>::iterator low,up;
13 |
14 |     sort (v.begin(), v.end());                 // 10 10 10 20 20 20 30
        30
15 |
16 |     low=lower_bound (v.begin(), v.end(), 20); //           ^
17 |     up= upper_bound (v.begin(), v.end(), 20); //           ^
18 |
19 |     cout << "lower_bound_at_position_" << int(low- v.begin()) << endl
        ;
20 |     cout << "upper_bound_at_position_" << int(up - v.begin()) << endl
        ;
21 |
22 |     return 0;
23 | }

```

Output:

```

1 | lower_bound at position 3
2 | upper_bound at position 6

```


10.5.2 rotate

把数组后一半搬到前面

```
1 template <class ForwardIterator>
2     void rotate ( ForwardIterator first, ForwardIterator middle,
3                   ForwardIterator last );
```

10.5.3 nth_element

```
1 template <class RandomAccessIterator>
2     void nth_element ( RandomAccessIterator first,
3                       RandomAccessIterator nth,
4                       RandomAccessIterator last );
5 template <class RandomAccessIterator, class Compare>
6     void nth_element ( RandomAccessIterator first,
7                       RandomAccessIterator nth,
8                       RandomAccessIterator last, Compare comp );
```

10.5.4 bitset

取用

```
1 bitset<4> mybits;
2
3 mybits[1]=1;           // 0010
4 mybits[2]=mybits[1];   // 0110
```

翻转

```
1 bitset<4> mybits (string("0001"));
2
3 cout << mybits.flip(2) << endl;    // 0101
4 cout << mybits.flip() << endl;     // 1010
```

运算

```
1 bitset<4> first (string("1001"));
2 bitset<4> second (string("0011"));
3
4 cout << (first^=second) << endl;    // 1010 (XOR,assign)
5 cout << (first&=second) << endl;    // 0010 (AND,assign)
6 cout << (first|=second) << endl;    // 0011 (OR,assign)
7
8 cout << (first<<=2) << endl;        // 1100 (SHL,assign)
9 cout << (first>>=1) << endl;        // 0110 (SHR,assign)
10
11 cout << (~second) << endl;         // 1100 (NOT)
12 cout << (second<<1) << endl;       // 0110 (SHL)
13 cout << (second>>1) << endl;       // 0001 (SHR)
14
```

```

15 cout << (first==second) << endl;           // false (0110==0011)
16 cout << (first!=second) << endl;           // true  (0110!=0011)
17
18 cout << (first&second) << endl;             // 0010
19 cout << (first|second) << endl;             // 0111
20 cout << (first^second) << endl;             // 0101

```

10.5.5 multimap

遍历

```

1 multimap<char,int> mymm;
2 multimap<char,int>::iterator it;
3 char c;
4
5 mymm.insert(pair<char,int>('x',50));
6 mymm.insert(pair<char,int>('y',100));
7 mymm.insert(pair<char,int>('y',150));
8 mymm.insert(pair<char,int>('y',200));
9 mymm.insert(pair<char,int>('z',250));
10 mymm.insert(pair<char,int>('z',300));
11
12 for (c='x'; c<='z'; c++)
13 {
14     cout << "There are " << (int)mymm.count(c);
15     cout << " elements with key " << c << ":";
16     for (it=mymm.equal_range(c).first; it!=mymm.equal_range(c).second; ++it)
17         cout << " " << (*it).second;
18     cout << endl;
19 }
20 /*
21 Output:
22
23 There are 1 elements with key x: 50
24 There are 3 elements with key y: 100 150 200
25 There are 2 elements with key z: 250 300
26 */

```

二分查找

```

1 multimap<char,int> mymultimap;
2 multimap<char,int>::iterator it,itlow,itup;
3
4 mymultimap.insert(pair<char,int>('a',10));
5 mymultimap.insert(pair<char,int>('b',121));
6 mymultimap.insert(pair<char,int>('c',1001));
7 mymultimap.insert(pair<char,int>('c',2002));
8 mymultimap.insert(pair<char,int>('d',11011));
9 mymultimap.insert(pair<char,int>('e',44));
10

```

```

11 itlow=mymultimap.lower_bound ('b'); // itlow points to b
12 itup=mymultimap.upper_bound ('d'); // itup points to e (not d)
13
14 // print range [itlow,itup):
15 for ( it=itlow ; it != itup; it++ )
16     cout << (*it).first << "□=>□" << (*it).second << endl;
17
18 /*
19 Output:
20
21 b => 121
22 c => 1001
23 c => 2002
24 d => 11011
25 */
    删除

```

```

1 multimap<char,int> mymultimap;
2 multimap<char,int>::iterator it;
3
4 // insert some values:
5 mymultimap.insert(pair<char,int>('a',10));
6 mymultimap.insert(pair<char,int>('b',20));
7 mymultimap.insert(pair<char,int>('b',30));
8 mymultimap.insert(pair<char,int>('c',40));
9 mymultimap.insert(pair<char,int>('d',50));
10 mymultimap.insert(pair<char,int>('d',60));
11 mymultimap.insert(pair<char,int>('e',70));
12 mymultimap.insert(pair<char,int>('f',80));
13
14 it=mymultimap.find('b');
15 mymultimap.erase (it); // erasing by iterator
    (1 element)
16
17 mymultimap.erase ('d'); // erasing by key (2
    elements)
18
19 it=mymultimap.find ('e');
20 mymultimap.erase ( it, mymultimap.end() ); // erasing by range
21
22 // show content:
23 for ( it=mymultimap.begin() ; it != mymultimap.end(); it++ )
24     cout << (*it).first << "□=>□" << (*it).second << endl;
25
26 /*
27 Output:
28
29 a => 10
30 b => 30
31 c => 40
32 */

```

10.6 位运算

10.6.1 基本操作

注意括号

功能	示例	位运算
去掉最后一位	$(101101 \rightarrow 10110)$	$x \text{ shr } 1$
在最后加一个0	$(101101 \rightarrow 1011010)$	$x \text{ shl } 1$
在最后加一个1	$(101101 \rightarrow 1011011)$	$x \text{ shl } 1 + 1$
把最后一位变成1	$(101100 \rightarrow 101101)$	$x \text{ or } 1$
把最后一位变成0	$(101101 \rightarrow 101100)$	$x \text{ or } 1 - 1$
最后一位取反	$(101101 \rightarrow 101100)$	$x \text{ xor } 1$
把右数第 k 位变成1	$(101001 \rightarrow 101101, k = 3)$	$x \text{ or } (1 \text{ shl } (k-1))$
把右数第 k 位变成0	$(101101 \rightarrow 101001, k = 3)$	$x \text{ and not } (1 \text{ shl } (k-1))$
右数第 k 位取反	$(101001 \rightarrow 101101, k = 3)$	$x \text{ xor } (1 \text{ shl } (k-1))$
取末三位	$(1101101 \rightarrow 101)$	$x \text{ and } 7$
取末 k 位	$(1101101 \rightarrow 1101, k = 5)$	$x \text{ and } (1 \text{ shl } k - 1)$
取右数第 k 位	$(1101101 \rightarrow 1, k = 4)$	$x \text{ shr } (k-1) \text{ and } 1$
把末 k 位变成1	$(101001 \rightarrow 101111, k = 4)$	$x \text{ or } (1 \text{ shl } k - 1)$
末 k 位取反	$(101001 \rightarrow 100110, k = 4)$	$x \text{ xor } (1 \text{ shl } k - 1)$
把右边连续的1变成0	$(100101111 \rightarrow 100100000)$	$x \text{ and } (x + 1)$
把右起第一个0变成1	$(100101111 \rightarrow 100111111)$	$x \text{ or } (x + 1)$
把右边连续的0变成1	$(11011000 \rightarrow 11011111)$	$x \text{ or } (x - 1)$
取右边连续的1	$(100101111 \rightarrow 1111)$	$(x \text{ xor } (x + 1)) \text{ shr } 1$
去掉右起第一个1的左边	$(100101000 \rightarrow 1000)$	$x \text{ and } (x \text{ xor } (x - 1))$

10.6.2 枚举长为 n 含 k 个1的01串

```

1 | int n = 5, k = 3;
2 | for (int s = (1 << k) - 1, u = 1 << n; s < u;)
3 | {
4 |     for (int i = 0; i < n; i++)
5 |         printf("%d", (((s >> (n - 1 - i)) & 1) == 1));
6 |     printf("\n");
7 |
8 |     int b = s & -s;
9 |     s = (s + b) | (((s ^ (s + b)) >> 2) / b);
10| }
```

10.7 其它

10.7.1 对跑脚本

```

1 | while true; do
2 |     ./gen > input
3 |     ./sol < input > output.sol
4 |     ./bf < input > output.bf
5 |
6 |     diff output.sol output.bf
```

```
7 |   if [ $? -ne 0 ] ; then break; fi
8 | done
```